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THE
TEACHING OF SCIENCE

L. GHANSHAM DASS P. E. S. (Rtd.)
PRINCIPAL
GOVERNMENT TRAINING COLLEGE
JULLUNDUR

FIFTH EDITION

INDIAN BRANCH
OXFORD UNIVERSITY PRESS
1963

Oxford University Press, Amen House, London E.C.4.
GLASGOW NEW YORK TORONTO MELBOURNE WELLINGTON
BOMBAY CALCUTTA MADRAS KARACHI LAHORE DACCA
CAPE TOWN SALISBURY NAIROBI IBADAN ACCRA
KUALA LUMPUR HONG KONG

First edition 1942
Second edition 1949
Third edition 1955
Fourth edition 1957
(all published as *The Teaching of Physics and Chemistry*)
Fifth edition (published as *The Teaching of Science*) *1963*

Printed in India by S. C. Ghose at the Calcutta Press Private Limited, 1 Wellington Square, Calcutta-13 and published by John Brown, Oxford University Press, Mercantile Buildings, Calcutta-1

PREFACE

THE need for a book on the teaching of science in Indian schools has long been felt. There are excellent books on the subject written by English authors about conditions of science teaching in English schools, but these can help the science teacher in India only in part.

In this little book I have tried to discusss the various methods of science teaching, the equipment required, the choice of a curriculum and the general management of a science department from the point of view of their suitability to the conditions of an Indian school. The views expressed are the result of my experience of teaching the subject for over 25 years in one of the premier training institutions of the country. The book, accordingly, is meant to serve as a help to pupil teachers and a guide to young science teachers in India.

In a work of this kind it was inevitable that certain of the topics discussed and views expressed by other writers had to be repeated in order that the subject may be presented as a whole and in a systematic way. I, therefore, gratefully acknowledge the help I received and the quotations I have taken from excellent books such as *Teaching of Science in Schools* by John Brown (University of London Press), *Science Teaching* by F. W. Westaway (Blackie), *Teaching of Science* by W. L. Sumner (Blackwell), *Teaching of Science* by F. Hodson (Chapman), *The Teaching of Scientific Method* by H. E. Armstrong (Macmillan), *The Teaching of Chemistry in Secondary Schools* by A. Smith and E. H. Hall (Longmans), *Practical Chemistry* by E. J. Holmyard (G. Bell), *Assignments in Practical Elementary Science* by R. H. Whitehouse (Macmillan), *The Teaching of General Science*, Vols. I & II (John Murray) and a number of other pamphlets and memoranda.

My grateful thanks are in no small measure due to my revered teacher, Dr R. H. Whitehouse, D.SC., I.E.S., formerly Principal and Professor of Science at the Central Training College, Lahore, who was the harbinger of a new era in science teaching in the Punjab.

Jullundur 1948

L. G. D.

PREFACE TO THE FIFTH EDITION

The book has been thoroughly revised and brought up to date. The revised syllabus for general science in the Primary and Middle classes in the Punjab has been incorporated. The scheme for Multipurpose High Schools has been discussed and the syllabus prescribed by the Punjab University for general science in Higher Secondary classes has been added. A brief note on the teaching of biology and notes of lessons on two biological topics have been incorporated. The revised syllabus in the method of teaching science for the B. T. examination of the Punjab University has also been given. A selection of questions set in the B. T. and B. Ed. examinations of various Universities for the paper on the teaching of science has been added. The list of general science books given at the end has been expanded.

New Delhi, 1961.

L. G. Dass

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I. THE IMPORTANCE OF SCIENCE AS A SCHOOL SUBJECT

THERE was a time when science was considered the refuge of the destitute and was only taught to those who failed on the classical side or were judged inferior in intellect. About the year 1860 Herbert Spencer wrote, 'science forms scarcely an appreciable element in our so-called civilized training'. In another place he spoke of science as 'that which our school course left entirely out'.

After a good many years of active and persistent effort, however, the claims of science for a place in the school curriculum have come to be recognized. There are few people, nowadays, who need convincing that it is wise to include science in the school curriculum. One may inquire, 'What has brought about this victory?' These are some of the reasons which have been advanced:

1. Some maintain that science provides a unique training in observation and reasoning. It makes people careful and systematic by training them in the co-ordination of their observation. It teaches the learner to reason from definitely ascertained facts and to form a clear judgement. It imparts a training in truth and demands of its votaries honesty and integrity of the most rigid type. Every word in scientific literature should be written consciously. To arrive at any scientific formula requires absolute detachment of mind in the scientist; he must discount his personal reactions and prejudices, if his results are not to be vitiated. These desirable habits acquired as a result of accurate experimentation are often carried over into one's general character and manner of living. Science is also an example of the unity between thought and action, as it concerns itself with both theory and application.

2. Others would have science taught because it is of great practical value. Herbert Spencer, in his essay 'What

Knowledge is of Most Worth', says that 'the information which the study of science furnishes is incomparably more useful for our guidance in life than any other kind'. Some knowledge of the present position and progress of science is necessary to obtain an adequate understanding of the world in which we live. Science is making such great contributions to the prosperity of the human race and is adding so rapidly to the sum total of our knowledge that nobody can afford to neglect a study of this subject. We live in a world of scientific achievement: we converse and carry on business daily by telephone; the telegraph provides us with a speedy means of communication; wireless apparatus is used daily in millions of homes; our houses, streets and shops are lighted by electricity and our machines, trains and trams are worked by electricity. In fact, so much depends on the applications of electricity that life would stand still without them. The discovery of the internal-combustion engine has made transport wonderfully easy and cheap. The steam locomotive, the ocean liner, and the aeroplane have brought places much closer together. The cinema has provided cheap entertainment. The new triumphs and miracles in medical and surgical fields are helping to reduce the misery of suffering humanity. In short, science has brought us comforts which kings could not dream of a century ago.

Science can also prove an instrument of destruction. The same coal-tar which gives useful products like dyes, medicines and disinfectants, can yield high explosives and irritant gases for the destruction of human life; the aeroplane, the quickest of all means of transport, can become the most terrible weapon of destruction. The discoveries of modern science have put into the hands of governments unprecedented powers for both good and evil. Unless the statesmen who wield these powers have at least an elementary understanding of their nature, it is scarcely likely that they will use them wisely. The modern theory

and practice of nuclear physics has made evident with dramatic suddenness that complete ignorance of the world of science is no longer compatible with survival. These manifold potentialities have to be reckoned with in daily life. 'The future, therefore, can only be secure in the hands of a race of people who grasp the significance of the changes which scientific discovery has wrought. No statesman, sociologist or economist can afford to neglect them.'[1]

3. Others (notably Professor H. E. Armstrong) maintain that science is taught in order to provide a training in, and knowledge of, what is called the scientific method. The method learnt at school will, it is hoped, prove useful later on in estimating social problems.

4. Science has a cultural value. The history of scientific discovery presents to the imagination vivid pictures of the work of great men and thus 'places science in the front rank of humanistic studies'.[2] A knowledge of the methods of observation and experiment imparted by the study of the different branches of science leads to the development of a logical mind, a critical judgement and a capacity for systematic organization, while a knowledge of the great questions with which science as a whole is concerned produces that breadth of imagination which is essential for the proper solution of the problems of life. Science induces a sense of humility in the face of the mysteries of nature. It fosters co-operation among workers in the same field in different countries. Its brotherly spirit makes for international understanding. Science, therefore, is too important an element to be omitted from general education. It is an important part of liberal education, of the equipment and preparation for life which the school is expected to give to its pupils so that they may become intelligent and useful members of the community.

[1] Sumner, W. L., *The Teaching of Science* (Blackwell), p. 6.

[2] Westaway, F. W., *Science Teaching* (Blackie), p. 10.

5. One great problem before the educationist is to train the child to use his leisure properly both in his formative years and later in life. Science is a great aid to the teacher in this respect, for many of the subjects with which people occupy themselves out of working hours are connected with science more or less directly.

6. Lastly, science is useful in that it forms, directly or indirectly, the basis of many of the studies of a purely vocational nature.

The Objective of Good Science Teaching

From the foregoing it should be clear that the chief reason for giving science a place in the school curriculum is that a general education is not complete if it does not include some acquaintance with natural phenomena, the physical laws and properties of matter and the applications of scientific principles met with in our daily life. We should not, therefore, teach science with a view to making each pupil a future specialist but we should try to make him a useful citizen. We must remember that a majority of pupils give up the study of science in later life and only a few enter employment in which a technical knowledge of certain fields of science is of direct value.

In consequence, it is clear that our school science course should be more general, based on humanistic lines so that it may be of value to all pupils. The school science course should form part of a sound general education, and not be designed for future science specialists who form only a small minority.

The objective of good science teaching as defined by Sir J. J. Thomson in his report on the position of natural science in the educational system of Great Britain[1] is two-fold. According to this report a course in science should fulfil two functions:

[1] *Natural Science in Education* (H.M.S.O.), p. 58.

1. It should train the mind of the student to reason about things he has observed and develop his powers of weighing and interpreting evidence.

2. It should also make him acquainted with the broad outlines of great scientific principles, with the ways these are exemplified in familiar phenomena and with their application to the service of man.

These two important points should be recognized and school courses framed accordingly.

At present the field covered in the usual science course of our schools is much too restricted, with the result that pupils leave schools, and even colleges, after several years of studying science, and yet they know very little of broad general science topics, and nothing at all of certain important branches of science. They possess little or no love of the subject and have no knowledge of the more humanistic and inspirational side of it. 'They are never thrilled by the romance of science or by the triumphs of modern engineering. The history of the subject, and lives of the great pioneers of science are a closed book to them. They may be able to find the specific heat of a metal accurately to two or three places of decimals, the coefficient of expansion of a metal, the hydrogen equivalent of zinc and yet have no idea of the generation of electricity for town supply or the main principles involved in an internal-combustion engine. After an advanced course in electricity and magnetism they may be unable to rectify a simple fault in an electric bell or to repair a fuse.'[1]

All this is due to over-emphasizing the formal training, allowing experimental work to become an end in itself, and underrating the value of the work at the demonstration table.

An effort should, therefore, be made to reach a position

[1] Brown, John, *Teaching Science in Schools* (University of London Press), p. 13.

in which experimental work by pupils, demonstration work by the teacher, and extra study by pupils will all have their legitimate places and proper proportions. How this can be brought about will be discussed in the next chapter.

II. TEACHING METHODS

Theoretical Teaching

From time to time various methods have been advocated for teaching science. Many of them are in use, for in each of them there is something to recommend it, and each in the hands of a capable and enthusiastic teacher can be made successful. Below are discussed some of these methods, their advantages and disadvantages, and how far they are applicable to conditions in our schools.

The Lecture Method

The lecture method is an attractive and easy method of teaching. It gives both teacher and pupil a great sense of satisfaction with their progress. Although the lecture may be very clear and good, however, it fails in one important respect. The teacher does everything. The boy is helped over all his difficulties; he is merely a passive listener. In a few sentences the teacher sums up centuries of experimental work. The pupil's attention, understanding and memory are all exercised, but the powers of observation and reasoning from observation—which the study of physical science ought pre-eminently to exercise—do not receive due stimulus.

The Heuristic Method

The writings and teaching of H. E. Armstrong, Professor of Chemistry at the City and Guilds Institute, London, have had much influence in promoting science teaching in schools. He was a strong advocate of a special type of laboratory training—heuristic training,[1] and argued that the true spirit of science was original investigation

[1] 'Heuristic' is derived from a Greek word meaning 'to discover'.

and discovery. The pupil was, therefore, to be put in the position of an original investigator and made to discover the principle for himself.

Professor Armstrong describes the heuristic method in the following words: 'Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their *finding out* instead of being merely told about things.'

The method requires the student to solve a number of problems experimentally. Accurate measurements and quantitative results are the basis of the method. Each student is required to discover everything for himself and is to be told nothing. He is given a paper of instructions relating to the problem in hand. He must follow the instructions, and enter in his notebook an account of what he has done and the result arrived at. He must also put down his conclusion as to the bearing which the result has on the problem in hand. In this way he is led to reason from observation.

'Essentially, therefore, the heuristic method is intended to provide a training in *method*. Knowledge is a secondary consideration altogether. The method is formative rather than informational. Such training, if properly carried out, does cultivate painstaking and observant habits and encourages intelligent and independent reasoning. It does bring home to boys clear notions of the nature of experimental evidence, and boys do learn that answers to questions can often be obtained from experiments they can work for themselves.'[1]

The method, however, presupposes a very small class and a gifted teacher. Even then the progress is very slow. Far too much time is taken up by 'investigation', the knowledge gained being very inadequate. Also, there is

[1] Westaway, F. W., *Science Teaching* (Blackie, 1929), p. 26.

a tendency to emphasize those branches and parts of the subject which lend themselves to heuristic treatment and to ignore important branches of the subject which do not involve measurement and quantitative work and are therefore not so suitable. Students, therefore, get a wrong idea of the nature of science as a whole. They grow up in the belief that science is something to be done in a laboratory, forgetting that laboratories were made for science and not science for laboratories.

Even in the case of single branches of science like physics or chemistry, 'the succession of exercises is rarely planned to fit into a general scheme for building up the subject completely'[1]; items are chosen just because they lend themselves specially well to the method. In many cases experiments are done merely for the sake of doing them, and time is wasted over those experiments which are beyond the pupils' skill and ought only to be performed by the teacher. As a result the science course is very limited in range, the ground is covered slowly, and pupils leave school with little or no scientific appreciation of their physical environment. 'The romance of modern scientific discovery and invention is a sealed book to them and the humanizing influence of the subject has been kept entirely from them.'[2]

Much is said in favour of the heuristic method because it leads pupils to discover scientific principles. But the question is how much does the pupil really discover for himself. 'A beginner in science may "discover" a test-tube hidden in a drawer but rarely a principle lurking in a group of facts.'[3] He is in the false position of one who knows that he is not really a discoverer, as he had full knowledge of the answer before he began work. It is

[1] Westaway, F. W., *Science Teaching* (Blackie, 1929), p. 26.
[2] Brown, John, *Teaching Science in Schools* (University of London Press, 1925), p. 22.
[3] Westaway, F. W., *Science Teaching* (Blackie, 1929), p. 27.

doing the pupil a disservice to let him think he 'discovers'. 'Above all things science teaching demands intellectual honesty.'[1]

The Demonstration Method

The demonstration method differs from the lecture method in that while in a lecture the teacher merely talks, in a demonstration he really teaches. The boys are active participants in a demonstration; they are passive listeners to a lecture. They are compelled to observe carefully, as they have to describe each step of the demonstration in accurate language. They are required to draw inferences from what they have observed, and these inferences should be discussed in the class. Lectures may be suitable for university students, but they are unsuitable for younger pupils who have not been trained to follow chains of reasoning. Pupils must be given a few points at a time, which must be fully understood before further ones are considered.

Constant questions and answers should form part of every demonstration lesson. Questions and cross-questions are necessary to illuminate the principle under discussion. Experiments are performed not merely to verify facts but to present new ones. The lesson should be illustrated with pictures, lantern-slides, cinema films and models, as these all help to arouse the interest of pupils. Their attention is riveted to the lesson and is not distracted by the difficulties of manipulation.

It is clear that the demonstration lesson in science is of such importance that nothing can take its place. It is the most stringent test of a good teacher. When the lesson is given effectively it saves time, enables a large field to be covered, is an excellent means of arousing enthusiasm and

[1] Westaway, F. W., *Science Teaching* (Blackie, 1929), p. 26.

provides an opportunity for the performance of experiments which are beyond the pupils' skill.

Below are given a few points which every young teacher of science and student in training should keep in view so that his demonstration lessons may be successful.

1. The manner of presenting the subject should be bright. The lesson should not consist of the 'dry bones' of an academic course taken during the teacher's student days. A breadth of treatment also is essential. The work should be applied to everyday experience; mention should be made of the practical achievements of science and, if possible, of the lives of great scientists with whom the work is associated. Pictures, posters, diagrams, slides, films, etc. should be used in addition to experiments to illustrate the topic in hand.

2. Sometimes the lesson suffers because of insufficient preparation by the teacher. Previous attention to details is necessary. The apparatus to be used should be tested beforehand and all experiments rehearsed, preferably under the same conditions as those under which they will have to be shown. In spite of this, something may go wrong at the actual lesson, so reserve apparatus is often useful. A calmness of manner should be cultivated. No other form of teaching gives a pupil such a feeling of disappointment as a badly prepared science lesson where nothing 'works'.

3. Experiments should be well spaced throughout the lesson.

4. Experiments should be striking, clear and convincing. If possible, experiments given in pupils' textbooks should not be repeated, but the principles should be illustrated with new experiments selected by the teacher from other books.

5. The results of experiments should not be disclosed beforehand; pupils should be made to observe carefully and build up reasonable conclusions on their observations.

6. The question of background should receive the careful attention of the teacher. Experiments with magnets and magnetic needles, for example, should not be shown against the blackboard—a black background. The teacher should make certain that every pupil can see the experiment. The seating of the class should be arranged with this purpose in mind, and when a boy is called to help the teacher he should not obstruct the view of others. The teacher should frequently pass specimens round so that pupils may have an opportunity of seeing and handling them.

7. Some form of prepared lesson notes is useful as a guide for the beginner. (The method of writing notes is discussed in Chapter VIII.)

The Assignment Method

The heuristic method is based exclusively on laboratory work. The lecture method and the demonstration method do not give any opportunity for laboratory work. Science teaching will be much more successful if training at the demonstration table and actual laboratory work can be combined. To achieve this, it is possible for a teacher, when planning a course of work, to divide experiments into two classes. First, those which he will show to the pupils at the demonstration table and secondly, those which can safely be left for the pupils to carry out themselves.

There is a danger in this system that we have to guard against—the practical work may be attempted in complete isolation from the theory. In the Punjab, the university has prescribed for matriculation classes a syllabus for theory and a separate syllabus for practical work in physics and chemistry. Very often we find that the available time on the time-table is devoted to theoretical teaching, and when this is finished and revised, the small amount of time left is devoted to the prescribed practical

experiments. In some schools where practical work is attempted side by side with theoretical teaching, it is not uncommon to find that while chemistry is being taught theoretically, experiments from the physics syllabus of practical work are being carried out in the laboratory. The theoretical teaching is thus divorced from the practical work in the same subject. Ideally, they should go hand in hand. The assignment method is the best way to achieve this.

The whole of the prescribed course in a subject is divided into so many connected weekly portions or assignments. One topic is taken and a set of instructions regarding its study is drawn up. The printed page containing instructions or the assignment is handed to pupils a week before their turn for the practical work. They read the pages of the textbook referred to in the assignment and write answers to a few questions (generally not more than three or four) in a notebook. The questions are framed with a view to test if they have read and understood the references. These notebooks are handed to the teacher a day before the practical work is to be done. The teacher examines the answers and points out the mistakes. The names of the successful pupils are entered in a progress chart kept in the laboratory. (See Diagram XIII.)

The second part of every assignment consists of laboratory work. Full instructions about practical work, i.e., fitting up of apparatus, recording of results, precautions to be taken, etc., must be given. On the day on which the practical work is to be carried out, the boys receive back their notebooks and correct their mistakes in the presence of the teacher. Those whose preparatory work is found satisfactory by the teacher are allowed to proceed with the practical work. A record of the practical work is kept in a second notebook.

On this system, generally two out of the six periods allotted to science on the time-table are reserved for

demonstration and four for practical work. In the two periods, the teacher may either give a demonstration on a topic which he considers too difficult to be done by the pupils themselves, or supplement the laboratory work of the pupils, so as to drive home facts and clarify things generally. Experience has shown that unless this is done, the knowledge gained from practical work remains shallow and nebulous.

From the foregoing it will be clear that the success of the assignment method depends on a properly drawn-up assignment. It will not be out of place to give below a few points which should be kept in view in drawing up an assignment:

1. An assignment must be based on one textbook.

2. The assignment should state what portions of the textbook are to be read. At the same time it should draw attention to particular points, give explanations of difficult points (in some cases even a paraphrase), and it should indicate those portions of unnecessary matter which the pupil may omit from his reading.

3. Questions should come next and must:
   - (i) be designed to test whether the student has read and understood the portion assigned
   - (ii) not require lengthy answers
   - (iii) frequently require diagrams to be drawn
   - (iv) ask for a list of apparatus for the coming laboratory work.

4. Extra reading. The teacher should indicate portions of books dealing with the same or allied topics. If possible more than one book should be mentioned.

5. The part of the assignment referring to practical work must include:
   - (i) what the teacher would ordinarily say in giving instructions
   - (ii) the method of recording results

(iii) the precautions to be taken, etc.

(iv) a diagram to illustrate the setting up of the apparatus if necessary.

(i), (ii), (iii) and (iv) above may frequently merely refer students to textbooks.

Below is given an example of an assignment on the preparation and properties of oxygen gas.

Preparation

Read paras. 30-4 on pp. 51-5 of *A New Matriculation Chemistry* by Ghansham Dass.[1] Note carefully the caution on p. 53. Answer the following:

1. What is the best method of preparing oxygen in the laboratory?
2. What precaution will you observe when you finish collecting the gas?
3. What are the important properties of oxygen?
4. Name the articles you will require for the preparation of oxygen and for testing a few of its properties.

Extra Study

1. *Achievements of Chemical Science*[2] pp. 91-3, describes the use of oxygen for rescue work in mines.
2. *Readable School Chemistry*,[3] pp. 50-2, describes the methods of manufacturing oxygen on a large scale. You may also study paragraph 35 of *A New Matriculation Chemistry* for the same purpose.

Laboratory Work

1. Fit up an apparatus for the preparation of oxygen gas as shown in Diagram V at the end of this book. Give special attention to the following points:

(i) The test-tube must slope slightly, mouth downwards.

[1] Published by Indian Press Ltd., Allahabad.
[2] Philip, J. C., *Achievements of Chemical Science* (Macmillan).
[3] Cochrane, J. A., *Readable School Chemistry* (Bell).

(ii) Wrap a piece of paper round the test-tube if the clamp is not supplied with a cork.
(iii) Clamp the test-tube near the cork end.
(iv) Make sure that the water well covers the beehive shelf.
(v) See that the jars are full of water.

2. Grind together in a mortar about half a test-tube of potassium chlorate and a quarter of that quantity of manganese dioxide. Put the mixture into the tube.

3. Heat the mixture, starting at the cork end and gradually moving the flame backwards.

4. Collect four jars of the gas after allowing the first few bubbles to escape as they are pushed out of the tube by oxygen.

5. Take hold of the retort-stand and lift it till the delivery-tube is out of water. Now put out the flame.

6. Test the following properties of the gas:
(i) Colour
(ii) Smell
(iii) Does it support combustion?
(iv) Does it burn?
(v) Its effect on the two kinds of litmus papers
(vi) Its effect on burning sulphur and glowing charcoal.

Write down the results of the experiments in your note-book and draw a neat sketch of the apparatus on the left-hand page of the notebook.

In order to guide the science teacher who may like to try this method of teaching, a few hints on carrying it out successfully are given:

1. Students must do their preparatory work beforehand to the entire satisfaction of the teacher. If some fail to do so, they should not be allowed to proceed with the practical work, but should be made to do their preparatory work instead.

2. Mistakes that are found in the preparatory work should be corrected by the pupil before the practical work starts.

3. The teacher must see beforehand that the material

required is in stock, and that the pupils have their textbooks, assignment-books and notebooks.

4. All the time the pupils are working, the teacher should be with them inspecting their work and giving individual help where necessary. He should see that everything set out in the assignment is done in the proper order, and that all instructions are fully carried out. He should tick off the portions of the written work examined.

5. Practical work should be stopped five minutes before the period is over so that all the apparatus can be cleaned, dried and put away by the pupils.

6. All records of practical work, including the drawing of diagrams, must be finished in the laboratory. If the work is not finished, the notebooks should be kept in the laboratory so that pupils may come and complete the work in their spare time.

7. No new experiment should be allowed to be started until the last one has been written off by the teacher as satisfactory in the progress chart.

This method has a number of advantages:

1. The burden of work is on the pupils, which teaches them responsibility. They should be made to sign a contract card. (See Diagram XIV.)

2. Pupils learn to consult books and get into the way of reading books other than textbooks—a habit so rarely found among Indian pupils.

3. Progress charts show at a glance how a pupil is getting on. A healthy sense of competition grows among the class.

4. The teacher gets an idea of each pupil's capabilities far more correctly than he would from any examination.

5. Bright pupils are not kept back, for they can start a new assignment earlier than other members of the class if they finish the last one in less time to the satisfaction of the teacher.

6. Dull pupils are not unduly pushed forward but allowed to work at their own speed, though they should be

2

encouraged by the examples of better pupils to get ahead faster.

7. A large quantity of one type of apparatus is not required by one class, as different experiments are going on at the same time owing to the varied progress of pupils. This diversity of experiments should be encouraged by the teacher.

8. There is greater emphasis on the practical side. Lesson demonstrations, though essential, usually supplement assignments.

We may as well mention a few handicaps that are likely to come in the way of the young teacher wishing to follow this method and suggest how they can be overcome.

1. Language difficulty. This can be overcome to some extent by explaining in the assignment the difficult passages in the textbooks.

2. The system depends on a well drawn-up assignment. Many teachers have not the time or the patience to do this work. This difficulty can be overcome by using the book of assignments prepared by Dr Whitehouse.[1] If, however, a textbook other than Gregory and Hodges' *Experimental Science* (on which Dr Whitehouse's book is based) is adopted, the corresponding pages of that textbook will have to be substituted in the book of assignments.

3. The method takes up more time than others, but as the matriculation syllabus is rather limited it allows plenty of time to cover it.

4. It entails hard work for the teachers.

5. There is a danger that pupils may copy the answers to questions from one another. This can be avoided by limiting the number of questions to be answered at home, by setting questions requiring very short answers, and by occasional oral questions if copying is suspected.

[1] Whitehouse, R. H. and Mabel, *Assignments in Practical Elementary Science for Matriculation Classes* (Macmillan).

6. Much of the success of the system depends on a well-equipped laboratory and a good library. These are often absent. It is, therefore, desirable to have a central circulating library of general science books open to all teachers of the province. Teachers may join this library by paying a small membership fee and be allowed to borrow a certain number of books each month.

The Historical Method

Some teachers prefer to develop a subject, not by first establishing accepted principles, but by following the stages through which the subject has passed in the actual course of development from its early beginnings. In tracing the growth of a theory through the slow stages of its evolution there is a fascination which appeals to pupils. Moreover, the human side of the subject is continually before the students, 'for the development of the subject from the original crude attempts at forming hypotheses to the modern refined methods of investigation forms an attractive study'.[1]

Chemistry in particular lends itself well to this treatment. The gradual development of the atomic theory, for example, can be unfolded historically in a very interesting way. Mechanics, astronomy and geology can also be developed historically in an easy way. Again, well-known stories from the history of science, such as Archimedes and his bath, Newton and the apple, etc., always appeal to pupils and may be made the means of arousing interest.

The Concentric Method

This is a system of organizing a course rather than a method of teaching. It is, therefore, better to call it the concentric system. It is based on the principle that a

[1] Brown, John, *Teaching Science in Schools* (University of London Press), p. 58.

subject cannot be given an exhaustive treatment at the first stage. To begin with, a simple presentation of the subject in outline is given, gaps are filled in the following year and more gaps a year or two later, in accordance with the amount of knowledge which pupils are capable of assimilating at each stage of their course. In each successive year, the circles keep widening till finally the subject is dealt with intensively.

This method of organization is decidedly superior to that in which one subject is taken each year, treated exhaustively and disposed of before the next subject is taken up. The system is most successful where the teaching is in the hands of one teacher, for he can preserve continuity in the teaching and keep his expanding circles concentric. If the teaching is in the hands of different teachers in successive years, there is apt to be too much repetition with the result that the subject loses freshness and power of appeal. The teacher who uses the concentric system must bear in mind that he should not exhaust the charm of the subject in the first year. Each year there must be something new—new problems to solve and new difficulties to overcome.

The Topic Method

The science course instead of consisting of a series of subjects such as physics, chemistry, botany, etc., consists of a series of topics around which the science lessons are planned. The utility of the subject will be better appreciated by the pupils if taught in the form of topics of immediate interest to them. Hence the topics should be such as have a direct bearing on or correlation with the everyday experience of the pupils. Take *water*, for example. This can be made the basis for a number of lessons dealing with the physics and chemistry of water, e.g., lessons on evaporation, condensation, town water-supply, composition, hard and soft waters, and purification of water. In the same way lessons

on *air* would include lessons dealing with its physical, properties, barometer, pumps, chemical composition of air, properties of oxygen, nitrogen and carbon dioxide, combustion, ventilation, liquid air, compressed air, respiration, supply of air to airmen, miners and divers.

In America this method is varied slightly. The teacher announces one topic and the boys are asked to say what they already know about it. A discussion is held and questions which no member of the class can answer are noted down for investigation. The teacher eliminates those which he thinks are too difficult to deal with at that stage and plans a course for a term on the remainder. The great thing about such a course is that boys feel that it is their course and not something thrust upon them by authority.

This method can be put into practice only in those schools where the course is not prescribed by requirements of external examinations, and where the teacher is free to include in his science course whatever he feels of importance in everyday life which may be of interest to the majority of pupils after they leave school.

This method will work well in the hands of a teacher who has read widely. 'In reality, it is not so much a method of teaching as a method of approach to a subject. Its final aim is to work out main principles from accumulated facts rather than to make facts fit principles already established.'[1]

In some American schools the teacher, in place of establishing the principles in the orthodox way, or of announcing a topic as explained, hands over to the class a piece of mechanism, say an electric bell, and asks them to discover everything about it they can. He advises them to consult books, to ask questions of people and to come prepared after a week for discussion with him. In this

[1] Westaway, F. W., *Science Teaching* (Blackie), p. 38.

way a number of useful suggestions are collected. They are sorted out and arranged and a series of lessons planned. One great advantage of this plan is that the boys get very much interested in the work.

Practical Work

No course of science for boys or girls is complete if it does not include some practical work by individual pupils. The achievements of modern science are mainly due to the application of the experimental method. Centuries of purely deductive work did not produce the same utilitarian results as a few decades of experimental work. Again, 'learning by doing' is an old educational maxim, the truth of which cannot be denied from the teaching point of view. Practical classroom experiments broaden pupils' experience and develop initiative, resourcefulness and co-operation. Practical work should, therefore, form a prominent feature in any science course.

Out of the methods we have already discussed, the heuristic method is pre-eminently a laboratory method. This method, as has been shown, is unsuited to the conditions obtaining in our schools. The assignment method is the best method that seeks to combine theory and practice in a harmonious way. Even if this method is not adopted, practical work in the laboratory must be attempted. We will now discuss how this can be done, and what important principles a science teacher should keep in view so that his practical work is effective.

If the demonstration method is followed to teach theory, the important principle to remember is that the practical work should go hand in hand with the theoretical work. When a class is doing theoretical work in chemistry, it should do practical work too in chemistry during the time allotted to practical work.

In some laboratories a card system exists for giving the student a certain amount of guidance in his laboratory

work. Each student is given a card on which are set out instructions regarding the experiment he is to perform. The apparatus required is also detailed. The student reads the instructions and proceeds with the experiment.

The use of the cards saves time and worry for the teacher, but the system is stereotyped and makes no allowance for individuals. The practical work often has no relation to the lessons. Again, the cards do not sufficiently encourage careful observation and they 'reduce what always must be a matter of intelligence and judgement to a rule of thumb'.[1]

In introducing the student to practical work the teacher must be careful to see that the spirit of curiosity and delight is preserved. It is not uncommon for a student to enter a laboratory full of interesting apparatus only to find that the first work he has to do is to measure a straight line in inches and centimetres and arrive at an average of so many centimetres to an inch. This is followed by similar physical measurements, though he may be learning chemistry at the demonstration table.

It should be the endeavour of every science teacher to guard against 'cooking' of results by his pupils. This comes of attaching too much importance to final results and less importance to procedure. If this bad habit is not eradicated in its early stages, it persists right through to the university career of students. The teacher should insist that boys do not go to the balance room without first entering the data in their notebooks. They should not be allowed to erase any figures. If a wrong figure has been entered by mistake, the teacher must be shown this; the figure should then be crossed through and the correct figure inserted. Boys should not be allowed to calculate results or write the data on scraps of papers. All calcula-

[1] Sumner, W. L., *The Teaching of Science* (Blackwell, 1936), p. 47.

tions must be done on the left-hand page of the practical notebook.

A record of actual work done and observations made should be kept in a laboratory notebook. The record should be faithful. It should tell the complete story of all the happenings during a lesson period. If an experiment fails this should be mentioned and reasons indicated. It is not unusual to find boys drawing a sketch of apparatus they never used or writing out experiments they never performed. The record should be kept on the right-hand page, the left-hand page being left for the diagram and calculations. The record of the method should be brief and in the first person singular. In experiments such as the one for specific gravity where the data itself shows the stages in the method, there is no need to give a separate written account of the method. In the case of experiments with gases, the record of experiments to test the properties of the gas in question may be kept in three columns headed *Experiment*, *Observation*, and *Inference*. The precautions taken should be written at the end in the first person singular (past tense), e.g., 'I did not remove the delivery-tube from the water before removing the spirit-lamp under the test-tube containing the oxygen mixture.' All records should be made with black-lead pencil; the diagrams should be simple and well-labelled. The notebooks should be signed before the boys leave the laboratory, or, if incomplete, kept in the laboratory so that they may be completed by boys in their spare time. Boys should not be asked to copy laboratory notes in ink at home; this is a waste of energy. Notes written at the time of the experiment should be final. Copied notes are never faithful records of what has been done.

Very often a teacher is required to draw up suitable laboratory directions or instructions for practical work by pupils in the laboratory just as he draws up a course of

procedure for his demonstration work. The following points should be kept in view in doing this:

1. For beginners the directions should be detailed, not inadequate.

2. The pupils should not be told exactly what is going to happen, otherwise they would not engage in active observation but would work mechanically.

3. The main purpose of the experiment should be made definite and clear in the instructions.

Below are given specimen laboratory directions on two topics, the separation of a mixture, and the preparation of a gas.

The Separation of a Mixture of Salt, Sand and Sulphur

The process depends on the fact that only the salt is soluble in water and only the sulphur in carbon bisulphide.

Take a beaker and put into it about 3 or 4 grammes of the mixture. Put some water into the beaker and stir up the mixture for a few minutes.

Take a filter-paper, fold and fit it in a glass funnel.

Support the funnel in a stand and place a clean evaporating dish below it.

Pour the solution through the filter-paper and collect the clean liquid which runs through in the dish. When all the liquid has run through, put a few c.c. of water in the beaker, shake, and pour on to the filter-paper. Repeat two or three times. This will wash all the salt solution through into the dish. After the washing, carefully evaporate the solution in the dish to dryness. Salt will remain in the dish.

Place the funnel with the paper still in it in an iron cone. Put in a sand-tray heated by a spirit-lamp. The salt having been dissolved out by the water, the residue on the filter-paper consists of sand and sulphur. When it

is quite dry scrape it off into a dry test-tube and add a few c.c. of carbon bisulphide. Shake, and after a few minutes filter the liquid through a dry filter-paper into a dry evaporating dish. When all the liquid has run through, wash the residue on the paper two or three times with carbon bisulphide. Having washed the residue of sand thoroughly, take the paper out of the funnel and dry it by waving it about in the air. Carbon bisulphide is very volatile and will readily evaporate, leaving sand behind.

The filtrate consists of a solution of sulphur in carbon bisulphide. Place the dish containing this solution over a warm sand-bath or simply expose it to the air. Carbon bisulphide will evaporate leaving crystals of sulphur behind.

The Preparation of Ammonia Gas

Mix together equal weights of ammonium chloride and slaked lime.

Put some of the mixture in a test-tube. Into the mouth of the test-tube fit a cork carrying a glass tubing bent at a right angle with the longer arm facing upwards. (See Diagram VI.)

Invert over the delivery-tube a dry gas-jar standing on a cardboard disc or glass plate (having a hole) which is placed on a ring fastened to a retort-stand.

Heat the mixture gently moving the flame backwards and forwards along the tube. After a short time hold a red litmus paper near the mouth of the jar. If it turns blue the jar is full of the gas. Remove it, cover it with a disc and place it on the table. In this way collect three jars of the gas and perform the following experiments:

1. Note the colour and smell of the gas. It was collected by the downward displacement of air. Why? What do you know about its density compared with air?

2. Hold a lighted taper in a jar of the gas and note whether the gas will burn or support combustion.

3. Invert a second jar of the gas in a trough of water. Be sure not to remove the plate till under water. Shake a little. Note the great solubility of the gas. Test the resulting solution with red and blue litmus paper and say if the gas is acid or alkaline.

4. Pour a few drops of strong hydrochloric acid into a jar and invert it over the third jar of ammonia. Remove the glass plates between the jars and note the production of dense white clouds of ammonium chloride.

General Remarks

We have discussed some of the methods by which science may be taught in schools. A teacher is free to choose any one of them according to his tastes and circumstances. If he has wide interests and holds clear views on the aims of his science teaching he can be sure of success. Below are given some general suggestions that will help the teacher, irrespective of the method he cares to adopt, in making his science teaching more effective.

1. 'Whatever general method is adopted, in detail it should, as far as possible, be consistently inductive. Begin with the familiar facts of the pupil's daily experience and from the firm ground of such experience, lead the beginner, step by step, to the less readily comprehensible relations of things.'[1]

2. The teacher should endeavour throughout the course to maintain the interest and keenness of pupils. The longing to know about things is inherent in pupils. The science teacher should make the best use of it. He should not kill the keenness of his pupils by commencing his science course with a lesson on the definitions of the yard and metre in units of measurements, setting exercises in measuring lengths of lines, straight and curved, in unit inches and centimetres, and going through a dull course

[1] Westaway, F. W., *Science Teaching* (Blackie), p. 38.

of measurement of lengths, areas and volumes. These things may be necessary but not as an introduction to a science course. In fact, it would be best to include practical measurements in arithmetic lessons which will become more interesting and real by their inclusion.

3. No system of science teaching is likely to be effective unless it is animated by a spirit of search. By presenting the subject-matter in the form of a problem the spirit of inquiry is stimulated and it should be encouraged through the whole course of science teaching.

4. Teaching should be kept on a broad basis connected with daily life. In the first place, the syllabus should be a wide and general one so that it may be of interest and value to the majority of pupils. If the syllabus is prescribed by an extraneous authority, and the teacher has no hand in framing it, he can at least make its treatment broader by introducing in his teaching material and illustrations taken from a wide field of knowledge and experience. He can illustrate the principles by numerous examples of science in the service of man.

5. Reference should be made wherever possible to the work of eminent scientists. The lives and achievements of the great pioneers of science are always a source of inspiration to students, and an account of their failures and successes seldom fails to stimulate interest.

6. Pupils should be encouraged to make models which are of scientific interest. The teacher should show that experiments can be performed at home with tin cans, tumblers, bits of wire, pins and other odd pieces of material. Several distinguished men of science like Edison and Davy were daily interested in performing scientific experiments when quite young. They retained this interest throughout life. The joy of making something which works is very great. Electricity lends itself admirably to this sort of thing. Working models of motors, dynamos, bells, telephones, etc., can be assembled easily and cheaply.

7. Teachers should avoid the use of symbols, formulae and equations because they are quite meaningless to young pupils. They will, no doubt, be learnt and repeated but not understood. Phrases such as 'A liquid boils when its saturation pressure equals the pressure to which it is subjected' are nothing more than scientific jargon to boys in schools. Similarly, pupils may correctly repeat definitions of specific gravity or specific heat, but may not understand what they really mean. This is also the case with symbols, formulae and chemical equations.

Demonstration Lessons

It has been said before that the demonstration method is the one most generally followed by science teachers. It may not be out of place then to describe, for the guidance of young science teachers, how a demonstration lesson should be conducted in order that it may be successful.

1. *Preparation in advance.* Even though the teacher feels that he knows the topic he is going to teach, it is desirable that he should read through the relevant pages of the boys' textbooks beforehand. A teacher is apt to talk above the heads of the pupils. The textbook will help him in setting a limit to what he wishes to cover during a period and on a particular topic. The teacher should always draw up a plan of the lesson. It is useful if the successive stages of the lesson are noted down very briefly in a diary, or on a piece of paper, to be kept by the side of the teacher during the lesson. This will guide him at the time of the demonstration. This done, the teacher should next make a list of all the experiments he is going to demonstrate. The success of a demonstration depends mainly, if not wholly, on previous trial. Every experiment, no matter how simple, should be rehearsed beforehand, preferably in the classroom, so that similar conditions exist at the time of the actual demonstration. Preliminary preparation in the classroom should ensure that

everything will be at hand when needed and that nothing will have to be sent for during the demonstration, as such interruptions interfere with the pupils' attention.

2. *Starting a lesson.* Every teacher of science should remember that he is teaching a subject closely related to the pupils' lives. He should also bear in mind that he must awaken keenness and enthusiasm for the subject among his charges. Much depends on starting a lesson in the right way. Try to start each lesson with a common, familiar example, an anecdote or a short story, or even a simple, interesting experiment. We often find teachers who plunge straight to the subject-matter with a scientific question as an opening remark. For example, in a lesson on combustion the teacher starts by asking the question 'What is the composition of air?' with the result that there is no response from half the class. How much better it would be if the teacher, in the manner of the vivid story-teller, introduced the lesson by saying: 'From early times, indeed almost as long as man has been on the earth, thousands of years before any written records were made, people have been interested and awed by fire. Many primitive races still worship fire. Ever since man began to think of the causes of phenomena, the explanation of burning has aroused the keenest discussion, and you may be surprised to know that a satisfactory explanation was arrived at during . . . . Now we are going to investigate burning and we will find out what it is that allows things to burn.' Let the boys be made to feel that they are engaged on a problem of great importance; that the greatest minds have, in the past, struggled to solve the question with which they are entrusted. Begin the lesson with enthusiasm and represent the problem under discussion as of the greatest importance. This will arouse keenness which should lead to success.

3. *Delivery.* Another point that counts for the success of a demonstration is the proper delivery of the lesson. In

the first place the teacher must command the attention of every individual in the class. He must see to it that he is near enough to his class to keep every member in his angle of vision. He should occasionally study the eyes of his pupils, for a wandering eye frequently means a wandering mind.

As to voice, he should speak slowly, deliberately, and with clear enunciation, avoiding rapid, monotonous and continuous talking. The tone of his voice should resemble that used in relating an interesting experience, modulated to suit statement, question and answer. A uniformly low or a uniformly loud voice should be avoided. Pauses of 15-20 seconds' duration, introduced at suitable intervals help to attract the attention of inattentive pupils.

4. *Experimentation.* Demonstration in a classroom must be an example of the kind of work expected from boys in the laboratory. The teacher should resist the temptation to make an experiment succeed by illicit means. The materials to be used should be placed from left to right on the table in the order in which they will be required. Everything should be perfectly clean, apparatus neatly fitted and placed so that it can be seen by every member of the class. Neatness and order in the work on the table will promote the same qualities in the laboratory.

5. *Eduction.* To teach by well thought-out, judicious and unambiguous questions in logical sequence (the answers to which form a complete conclusion) is an ideal method, but such a method demands an exceedingly skilled questioner and a very careful preparation of each lesson. People with these qualities are rarely to be found, but experience and study will help the average teacher to improve in this direction.

Some teachers insist that it is unwise to disclose any knowledge to pupils, and they adhere to the principle that they can, with perseverance, make pupils supply the knowledge themselves. The result is usually most pain-

ful. Interest vanishes and utter confusion results. The best advice on this point is, if you can readily educe, by all means do so, but do not hesitate if difficulty is ahead to tell the pupils what you hoped they might tell you. It is faulty teaching always to tell pupils everything, but it is not wrong to tell them something.

6. *Blackboard work.* Few things count more towards the success of a demonstration than the proper use of a blackboard. The writing on the blackboard must always be in a good, clear and legible hand. 'Scribble' must never appear on the blackboard, for bad writing on the blackboard means bad writing in the pupils' books. Proper spacing too must be attended to. Economy in the use of blackboard space is another important requirement. Always begin from the top left-hand corner; do not start a second line until the first line has extended across the blackboard; do not divide words at the end of a line; keep all inset paragraphs under one another, and all similar signs in calculation under one another wherever possible.

In a science lesson it is convenient to reserve some space for sketches on the right-hand side of the blackboard. As regards the type of sketches, the teacher of science should remember that a science lesson is not concerned with the art of drawing but merely with the production of diagrams as distinct from pictures. There should be no attempt at perspective, but every part of the diagram should represent what would be seen if the eye were placed on a horizontal line with that part. Thus the circular top of a bottle should not appear as an ellipse, nor should the base of a retort-stand show any surface. Diagrams are frequently useless if not properly labelled. Objects which cannot possibly be mistaken—gas-jar, delivery-tube, cork, etc.,—need not be labelled. Letters and figures which refer to a list of apparatus given below the sketch are unsuitable and cause much waste of time. Dashed or

dotted lines should be used as indication lines and no arrow-head is necessary at either end of such a line. The indication line should go straight to the object labelled. When it is required to show by a sketch the conditions before and after an experiment it is better to draw a second sketch and not to alter the original. Pupils cannot make alterations without causing confusion in their sketches.

7. *Copying and supervision.* The blackboard is the best place on which to write every observation and inference obtained from the class so long as they are relevant to the matter being taught. It is, therefore, essential that the pupils should copy everything which is written on the blackboard. If this is not done the matter is lost for future reference.

Some people are of the opinion that pupils should not copy sketches but should make their own from the apparatus before them, and also write down their own notes rather than copy those on the blackboard. With regard to pupils making their own sketches, it is enough to say that this practice takes a long time and the results are invariably bad. The labour required in correcting this work is immense. After pupils become familiar with the style of sketches and have had some practice, they may be able to do the work unaided. With regard to pupils making their own notes, the important thing is that the language used is the language of the pupils and of the standard understood by them readily. If the teacher has obtained an answer or inference from several boys orally, and so long as the language is correct, it may safely be written on the blackboard and copied by all. The teacher should not put on the blackboard the inference in his own words or in a bookish style. So long as the pupils' language (corrected if necessary) is written on the blackboard there is an advantage in getting pupils to copy it.

Time is saved in correction, it guarantees proper expression and teaches correct spelling.

In order to assist pupils in taking down the blackboard summary correctly in their notebooks, periodically, or at the end of the lesson, the teacher should get amongst the pupils and inspect their work. In this way he is assured that entries are made, and such things as correctness and neatness can be checked there and then. Supervision includes the correction of bad postures and instruction as to the care of books.

Practical Work

We assume that the assignment has been given. The teacher has corrected the notebooks of the pupils a day before their turn for practical work, and has made a note of those who have not done their preparatory work satisfactorily and who will not be allowed to do practical work. He has also made sure that the apparatus for the coming practical work is in stock.

On the day fixed for practical work, the teacher will first of all distribute the notebooks and ask the pupils to correct their mistakes; he should also go round to see at a glance if the mistakes are corrected. Pupils are then allowed to proceed with the practical part of the assignments. The teacher may draw a sketch if he thinks it necessary, emphasize or remind them about the precautions if he thinks they are too important to be neglected. In rare cases he may give a demonstration of fitting up the apparatus, for example, when boys are only beginners, or when they all happen to be going wrong.

The teacher should then go round and help the pupils individually in setting up the apparatus, testing properties and performing experiments. He should also check and tick off any written record made by a pupil. This will reduce correction work at the end.

The laboratory is not a place for the discussion of pro-

blems. It is a workshop. So let pupils follow instructions given in the assignment and reserve discussion for some other time.

Individual work is preferable to working in pairs. Where pairs work together, there is a strong tendency for the keener boy to do all the work and the less keen or shy type to be pushed out. If working in pairs is occasionally resorted to, the teacher should see that the brighter boys do not do all the work.

A practice which is frequently resorted to in the laboratory is that of taking three readings and striking an average. It is said to lead to accuracy. It should be remembered that there are times when this practice is unscientific and a sheer waste of time, for example, in finding the weight of a given article, or in measuring the length of a line. There are times, however, when observations should be repeated three times, or even more, as in the case of finding a focal length where the human factor plays such a great part.

III. EQUIPMENT

The Laboratory and its Fittings

The work of designing and building a science room is that of the school architect. When, however, a new science block is projected, or repairs and alterations are being effected in the old, the science master should collaborate with the architect in planning for what is best from the educational point of view. It is for this latter purpose that the following details about the building, its furniture and fittings are given. The plan of a combined lecture room and laboratory for use in schools up to the matriculation standard, devised by Dr R. H. Whitehouse, formerly principal of the Central Training College, Lahore, has been adopted as the official standard plan by the Punjab Education Department. A copy of the plan, and drawings of the writing and laboratory tables advocated, and now used in almost all schools in the Punjab, are shown in diagrams at the end of the book.

It will be seen that Dr Whitehouse advocates a combined lecture room and laboratory of $45' \times 25'$ for a class of 40 boys in demonstration and 20 in practical work. This has obvious advantages:

(i) it is economical to build
(ii) there is an atmosphere of science
(iii) it provides comfortable writing accommodation
(iv) it affords an opportunity for better control
(v) a gallery is avoided.

Accommodation

The size suggested for a standard plan is $45' \times 25'$. This size has been specially chosen in view of the cheaper cost of erecting a new room 25′ wide against one of greater width, roof supports being a very important matter to be

considered in buildings, and because few existing school rooms will be less than 25′ wide. The length of 45′ is necessitated by the comparatively narrow width. For example, if 30′ wide the room need only be 40′ long. A long room has no special disadvantage, since the teacher will never be addressing a class filling the whole room; he will address at most forty boys occupying about half the room.

Seating accommodation is provided for forty boys at dual tables. This constitutes the lecture room. It will be used in its entirety during demonstration lessons. During practical work, it will be used partially, by half the class not directly engaged at the work benches, and by those doing practical for writing work if desired.

As regards construction, the walls are taken to be 1′ 6″ thick—a common thickness in this country. Taking the floors next, a perfectly smooth floor is preferable to one exhibiting any roughness, as it can be more easily cleaned. A conglomerate floor over lime concrete, covered by cement plaster, is recommended. It gives a perfectly smooth surface and is very easily kept clean. Though somewhat more expensive than brick, the advantages over the latter are obvious. Such a floor as that recommended when given a very slight slope, can be periodically swilled with ease, and for this purpose, as well as for the avoidance of dirt-lodging corners, round corners between the walls and the floor are strongly recommended.

Side lighting is given by three large windows, two near the seating accommodation and one near the practical benches. Each is 6′ across and may be 7′ or 8′ high. This should be ample, at least for the pupils seated at the writing tables, since they are on the north side with no veranda to reduce the light. If more light is thought necessary for the practical end, top lighting can be resorted to in addition to lighting by *roshandans* or

clerestory windows without sunshades. The windows open outwards so that the inner window-sills may be used as shelves if required. For darkening windows during light experiments a system of window-blinds can be fitted.

Entrance and exit should be by two doors, and it should be distinctly understood that the entrance should never be used as an exit and vice versa. An alternative plan, which may commend itself to some, is that one door should be used strictly for the classroom end and the other for the practical work end. Whichever is adopted, it must be recognized that rigid observance of the rules of entrance and exit must be insisted upon. A complete through draught can be obtained by opening both doors and windows. If the situation of a school is such as to enable wire-gauze screens to be dispensed with at the windows, for instance, in open places not adjacent to bazaars, so much the better for light and air. If wire-gauze screens are really necessary, the windows can be constructed with an upper and lower half, the latter fixed and the upper opening inwards, so that the convenience of a shelf is still retained. It may here be suggested that the plague of flies in laboratories can be kept down by the provision of a number of dishes containing a sugary solution of formalin of 2 to 3 per cent strength; flies usually drink in the early morning and if this solution is provided overnight the slaughter of flies will be considerable.

Doors, like windows, should open outwards, so that in case of panic for any reason the doorways cannot be blocked and prevent rapid exit.

If it can be afforded, paint or distemper is preferable to whitewash for the walls; in the long run it is cheaper since it will last several years, and the inconvenience attendant upon annual whitewashing is avoided.

Furnishing. (See Diagrams I—IV.)

Take the seating area first. A large blackboard, 10′ by

4′, is provided and it is merely a cemented area of the wall treated with blackboard paint. At three feet distance from this is the teacher's table, 6′ long by 2′ 6″ high. This height is given for two reasons: in the first place, the table can be used as the teacher's writing-table, and secondly, it must not be so high as to cause any inconvenience to the class watching demonstrations. It may not be so convenient for the teacher to have a low table for demonstration purposes, but demonstrations are not long continued and the needs of the class must be considered first. A raised platform for this table is not desirable.

The seating area for the class is on the same level as the rest of the room; there is no gallery. The gallery for smaller classes has been very overrated and it is merely a copy of the style of laboratories in colleges. A gallery is to be deprecated for several reasons. It is an expensive matter; it is more difficult to clean than a flat area; and it hinders supervision—the most important and the most neglected work of the teacher.

The seats consist of dual tables and chairs, and the cost of one dual table made of deodar wood, stained and varnished, together with two armless wooden chairs is about Rs 35. This will be found to be much less expensive than dual desks which usually cost about Rs 45 each. Twenty tables and forty chairs complete the equipment. The advantages of the table and chair system are:

(i) they are economical
(ii) they provide a perfectly natural seat—exactly the kind of seat for writing which is universally adopted outside the schoolroom
(iii) they allow a boy to pass readily to the passage-way between the tables and to stand erect without difficulty when addressed
(iv) they are easily moved for the sweeping of the room
(v) they are found useful for the accommodation of guests at all school functions.

The dimensions of the dual table are 3′ 6″ long, 1′ 6″ wide and 2′ high. A shelf for books is placed at a sufficient height to allow for the pupils' knees to go under the table when sitting.

In design the dual tables are perfectly plain. The tops are flat; a sloping top has little to recommend it and much to condemn it, since articles placed on it are liable to fall. Ink-well holes and grooves for pens and pencils have been omitted; they might be provided if specially desired. Holes and grooves reduce the available area; the filling of open ink-wells causes much disfigurement. Boys should be taught to take care that their ink-pots are not upset; they do not have ink-well holes in their tables at home. Teachers should insist on boys treating school furniture with the same care as they would treat furniture at home. The chairs are 1′ 6″ high in the seat which, in the case of an iron chair, may be covered with a small mat if desired.

The area allowed for a dual table and two chairs is a square of 3′ 6″; this is found to be ample, and even a little less from back to front is sufficient. The whole of the seating accommodation may be easily calculated and it will be found to occupy, for forty seats, 18′ 6″ by 17′ 6″. Passage-ways of 1′ 6″ are quite sufficient for single file, and a space of 2′ 6″ to 3′ 6″ at the sides will be enough.

A sink is provided for the teacher as shown in the plan. It may be of any convenient size; 18″×12″×6″ is a good size.

The laboratory tables are six in number arranged as shown. All the tables are perfectly plain and made of deodar wood. The only addition to the ordinary type of table is a shelf along the working sides just below the top for placing books and papers. No dust-lodging ornamentations such as 'turned' legs are permissible; the furniture throughout should be designed to avoid all ledges for dirt to lodge, as the laboratory must be as free as possible from dust and dirt. The whole of each table

should be stained dark and, except the top, varnished; the top should be treated with wax ironed in with a hot flat-iron so that the pores of the wood will be filled to prevent the easy penetration of liquids.

The tables measure 6′ by 3′ 6″ and stand 3′ high; each accommodates four boys. A working space between the tables of 3′ 6″ is allowed and experience has shown this to be quite sufficient; the space between the tables and the walls varies between 3′ and 4′ and the passage-way at the end of the tables is 2′ wide.

In the matter of working space, there is a great difference between college and school requirements. The space demanded in college laboratories cannot be allowed in schools of the future on account of the increased cost, and the absence of any real necessity for it. It may be safely asserted that the space allowed is wholly sufficient for school requirements.

It will be observed that a large blackboard space is provided at the laboratory end, and ample space for the teacher is also to be found between the blackboard and the opposite practical table.

The laboratory tables are not provided with sinks for several reasons:

1. *Economy.* Much plumbing and a network of drains are dispensed with and a saving of three sinks is effected. The number of experiments demanding considerable water-supply is small, and a trough of water will serve most purposes.

2. *Usefulness.* The table is equally useful both for chemistry and physics. The expensively fitted chemistry table is not well suited for physics, but a physics table can easily serve for chemical experiments. The absence of sinks gives more working surface, and the table can also be utilized for purposes other than science teaching if required.

3. *Appearance and Cleanliness.* The floor of the room

is not broken by unsightly drains which may harbour waste-water and dirt.

4. *Tidiness.* It is a matter of common experience that tables fitted with sinks are, in schools, invariably well splashed with water, which interferes with experiments and makes it almost impossible to keep writing materials and reference books free from damage.

No drawers or cupboards are provided in the tables. Such provision is again merely a copy of the type of bench used in colleges. It is always found that these drawers and cupboards are a harbour for waste paper, broken apparatus, and dust. The excuse for such luxuries is that each boy may keep his own apparatus in his own cupboard. There is no reason why any boy should have a separate set of apparatus; more than one boy will have to use the same apparatus and responsibility for it cannot be divided; unless the drawers and cupboards are locked after each lesson apparatus will not be safe in them, and the nuisance of locking and unlocking and the inconvenience of lost keys are better avoided. If the apparatus is put away in the almirahs after each lesson under the supervision of the teacher, a continual check is maintained and responsibility for damage or dirt can be immediately fixed.

Three sinks are fitted, one for the teacher and two for the pupils. Of the latter, one is placed in the window-recess and the other in a recess in the wall so that neither projects seriously into the room. Each is provided with a straight down-pipe leading to a bucket; a spare bucket should be kept in case of necessity. A draining-board, with grooves arranged to drip over the sink, is provided for each of the laboratory sinks, so that beakers, flasks, etc. may be inverted for drying and the water allowed to drain off.

For water-supply a galvanized iron tank $3' \times 3' \times 3'$ can be placed on the roof or in a corner on bricks and filled

regularly. Pipes will lead from this tank to the sinks. If this is considered costly, a galvanized drum of iron fitted with a brass stop-cock at the bottom may be placed by the side of each sink and regularly filled with water.

Recesses in the walls are suggested for balances; they are a foot wide, and the shelf so provided is placed at 3′ 3″ from the ground. The advantages of the recess over the wooden or stone shelf are:

(i) it costs less, since the masonry is less
(ii) it is far more substantial than a bracket shelf
(iii) it does not project into the room and is, therefore, economical of space. A length of 7′ to 7½′ is possible in each case, which should give ample accommodation for balances.

Storage accommodation is found in six large almirahs, each 7′ high and 5′ wide, having shelving accommodation about 1′ 6″ deep, 1′ being recessed in the wall which is 1′ 6″ thick and 6″ projecting into the room. This will probably prove more than enough, but abundant almirah space is seldom regretted. Reagent shelves could conveniently be placed on either side of the recesses for balances.

Notice-boards for assignments of work, results of tests, etc., may find a place on the wall between the windows or just inside the doors.

It is claimed for the laboratory shown in the plan at the end of this book that:

(i) by adopting the combined system it reduces costs
(ii) it is furnished simply, cheaply and serviceably for school work
(iii) it is compact and, though space is necessarily restricted, provides quite sufficient accommodation for a class of forty
(iv) blackboard space receives special attention
(v) storage accommodation is sufficient.

It is perhaps more particularly necessary in a science

room which serves a double purpose and which does not allow an excess of space that *laboratory discipline* must be insisted upon. The teacher who is indifferent in this respect cannot teach efficiently or obtain the best results. The following hints should be observed:

1. Every boy has his assigned place, which is indicated by his name written on a card placed in a brass card-holder fixed on a leg of the table; he will also have a place assigned to him at the writing tables. In no circumstances will he be allowed to move about the science room except with express permission.

2. It is expected that the teacher will be free during the period immediately preceding the lesson, so that he will be able to place out any apparatus required. If this is impossible boys at each table will be numbered 1 to 4; No. 1 from each table, acting directly under the orders of the teacher, can get four sets of the articles required for each table from the almirah.

3. The lesson should always stop 5 minutes before the end of the period. Under orders, apparatus on each table will be rapidly separated into dirty and clean apparatus, dirty at one end and clean at the other. No. 2 will promptly remove all dirty apparatus carefully to the draining-board to be washed. No. 3 will remove all clean apparatus to the almirah. No. 4 will wipe down the table with a duster. (Each table will be provided with a duster.) After all is clear and clean to the teacher's satisfaction, boys must quietly 'stand to' in their places, facing the teacher, and on command file out of the room.

4. Class monitors for the week will be found to be very useful assistants for cleaning dirty apparatus after school-hours or during recess.

5. For the correct alignment of all movable furniture, white or black lines can be painted on the floor, and pupils should be responsible for the correct alignment of their tables.

Such discipline should have a marked effect on the character of pupils, and orderly arrangement throughout should be one of the aims of science teaching.

Apparatus and its Upkeep

Selection and Purchase

Before purchasing, a list should be prepared of experiments to be performed by pupils and of principles to be demonstrated experimentally by the teacher. The supplies should be purchased accordingly, i.e., for experiments to be done by pupils, as many sets of apparatus as the number of pupils working at a time; for the demonstration experiments, at least one each of the articles required. It would be safer to buy a few additional articles in each case to guard against breakage. If 20 pupils are to work in the laboratory at a time, it is a good plan to order two dozen sets of every article.

Another principle to be kept in mind when selecting apparatus is that the teacher should not be tempted by attractive descriptions in a catalogue to buy articles which are seldom, if ever, required. Only articles which are really required should be purchased.

If money is insufficient for all purchases, the first consideration should be for beakers, flasks, funnels, and files—articles required for the pupils' practical work. After an ample stock of these has been acquired, materials useful for demonstration should be purchased. In addition to these, there are certain articles which should be present in every well-equipped laboratory. A photographic camera, magic lantern, model of a steam engine or telephone and models of other scientific appliances in daily use are very useful in a laboratory. These should be purchased when the urgent requirements of the pupils for practical work have been

fulfilled and enough apparatus for demonstration purposes is available. It is not uncommon to see a laboratory equipped with a pair of good telephones, a costly telescope or a prismatic binocular, but containing only half a dozen test-tube or a few beakers.

When making out an indent, full specifications of the kind of articles required should be given. For example, the capacity of beakers, flasks, retorts, and china dishes; the diameter and height of troughs, gas-jars and test-tubes; the gauge of wires, and whether bare or insulated, single covered or double covered, double silk-covered or cotton-covered; whether an article should be of glass, brass or iron; in the case of chemicals, whether commercial or pure, and so on. If full details are not given, the teacher, is likely to receive supplies he never intended to order.

It is wise to select a reliable firm which has a good reputation. In many cases it is better to visit the firm, make a selection and have the apparatus packed in one's presence. This saves the trouble of sending back unsuitable material.

The UNESCO-designed apparatus for tropical schools is very satisfactory. The Government of India is considering an arrangement for the manufacture of such instruments. If this is done and such apparatus is given to schools in lieu of cash grants for science teaching, it will solve a major problem confronting the science teacher.

Arrangement and Care

The apparatus should be carefully unpacked and, after checking with the list supplied, arranged in almirahs. The latter should have glass fronts and preferably be fitted with mortise locks to prevent dust getting in. The tops of the almirahs should be sloping so that no dust or dirt lodges there. Almirahs with sliding doors should be avoided for the doors swell and jam, dust gets inside them, only half the shelf can be opened up at a time, and they are inconveniently fastened at the bottom.

The apparatus should be arranged one deep on a shelf; several rows of the same article, however, may be placed on one shelf.

There are two ways of arranging the apparatus—subject-wise and alphabetically. The difficulty in arranging it subject-wise is that some articles fall under more than one heading. In the latter method of arrangement, glass and metal articles are likely to come together and there is a likelihood of breakage.

The arrangement which experience has shown to be satisfactory is to reserve a few almirahs, say four, for apparatus required for individual practical work. In these almirahs the apparatus may be arranged alphabetically. The letter of the alphabet should be put on the shelf containing articles beginning with the letter. A list should be hung outside each almirah showing the names and numbers of articles which it contains. Articles found short of this list should be replaced from stock from time to time.

The rest of the apparatus required for demonstration may be arranged subject-wise in the remaining almirahs.

As to the arrangement of chemicals, two open shelves can conveniently be fixed on either side of the recess for balances. In one should be placed six glass-stoppered bottles (8 oz. capacity) for each of the following chemicals: the three acids, ammonia solution, lime water, silver nitrate solution (brown or blue bottles), ferrous sulphate solution, litmus solution, barium nitrate or barium chloride solution, etc. The other shelf may contain one bottle each of chemicals such as nitre, salt, potassium chlorate, manganese dioxide, zinc, copper or iron filings. Dangerous chemicals like phosphorus or sodium, and costly ones like mercury, should be kept in a separate cupboard. The bottles should be provided with labels neatly written or typed and coated with paraffin wax.

The apparatus kept in the almirahs should be regularly

inspected, dusted, cleaned and occasionally polished. The following recipes will be helpful in this direction :

1. To clean brass articles use Brasso. Apply the polish evenly over the articles with the finger covered with a piece of muslin. When dry, rub off with a coarse duster.

2. To polish articles made of iron use black japan thinned with a little turpentine or kerosene. To remove rust use kerosene oil first. Vaseline should be applied on screws and hinges of iron articles during the rainy season.

3. To clean glass panes of almirahs use Monkey Brand soap. Rub a wet sponge over the soap and then over the pane and clean off with a duster. Pumice-stone dipped in water or dipped in methylated spirit and rubbed over the panes will remove all dirt. Burettes and flasks may be cleaned with a mixture made of potassium dichromate solution mixed with a little sulphuric acid.

4. To polish wood use spirit polish made by dissolving shellac in methylated spirit in the sun. One or two coats applied with a cotton wool plug will do.

5. The top of each laboratory table is unpolished but it should be waxed to avoid the action of acids. This is done with paraffin wax or a packet of candles. Melt the wax or candles in a big china vessel. With a painter's brush coat the wax over the top of each table. Take a hot dhobi's iron and pass it over the table so that the wax is spread evenly all over the surface. Let it dry. Now scrape off any excess of wax with a blunt knife and finally polish with a coarse duster.

Home-made Apparatus

A science teacher should be able to devise and make apparatus for simple experiments, to modify apparatus and to effect simple repairs. With this end in view, science teachers are advised to make themselves familiar with the common tools used by carpenters and metal workers. The apparatus devised and made in the school

workshop or laboratory by the teacher or pupils is called home-made apparatus. A teacher with vision, resource and ingenuity, and some manual skill, will be able to make a number of valuable and serviceable models with cheap materials such as jam-jars, tins, bits of wire, corks, motor parts and things picked up from second-hand wireless and cameras. There are many advantages in using home-made apparatus:

1. It is economical.

2. The application of science to life and things around us is made more obvious when using this type of apparatus in place of more expensive models.

3. The child is encouraged to make apparatus and working-models as a hobby.

4. Science is correlated with manual training.

5. It lends interest to the subject if one can get one's own models to work with.

6. It is a training for the exercise of resourcefulness, ingenuity and manual skill—qualities so useful in life.

7. The child gets a glimpse of the difficulties of the early scientists who had to work with this type of apparatus and may catch their enthusiasm for the subject.

It may, however, be stated that in using home-made apparatus in the laboratory we should not carry our enthusiasm too far. We should not sacrifice efficiency for the mere craze of home-made apparatus.

Library

A science library should be an essential part of the equipment of every school where science in any form is taught. It is a wonderful aid in the teaching of science, for by reading extra books pupils can obtain a good general knowledge of aspects of science which it is not possible for the teacher to deal with in the time at his disposal for class teaching.

The teacher should select for the library books covering

a wide range of topics. There should be books dealing with topics in physics, chemistry, biology, astronomy, geology and nature study; books on the romance of science, engineering, scientific discovery and invention; on the lives and achievements of famous scientists; on scientific hobbies like photography and radio. There should be standard books of reference for both the teacher and pupils. A few of the latest books on methods of teaching should be placed in the teacher's section.

It is not easy, even for experienced science teachers, to make a selection out of the multitude of books on science which are now available. In order to assist teachers in solving this difficulty a fairly exhaustive list of books on science is given at the end of this book. These will be found useful for school libraries.

Science teachers can compile lists of useful books themselves by getting catalogues from reputable publishers and reading specimen pages and tables of contents of books mentioned. They should also read reviews of books in *Nature*, *School Science Review*, *Discovery*, *Scientific American*, *Popular Mechanics*, *Popular Science* and *Industry*. All these are good journals for schools with the exception of *Nature*, which is useful for colleges only.

Charts, Diagrams and Pictures

The display in the laboratory of diagrams, pictures and illustrations of scientific interest serves to give it the right atmosphere. Printed charts from the bazaar should be avoided. They are costly and not fully representative; they sacrifice simplicity and directness to detail. They are generally hung at a great height on the walls and so are rarely looked at attentively by pupils.

Charts and diagrams of apparatus for display should be drawn by the teacher or pupils. They may be of the following types:

1. Charts showing diagrammatic sketches of different pieces of apparatus generally used by pupils in their practical work, for example, a beaker, flask, funnel, tripod, gas-jar, retort, spirit-lamp, etc. If specifications are put down under each, they will be of use when ordering apparatus.

2. Charts showing the preparation of oxygen, hydrogen, etc. The diagrams should be labelled and should be in simple outline drawn in either pencil or chalk on the appropriate paper.

3. Charts for demonstration purposes, for example, showing the working of a common pump or an air pump in stages, the charging of a gold-leaf electroscope by induction, etc.

Besides the above charts, the following types of pictures and illustrations will serve a useful purpose if exhibited in the laboratory :

1. Portraits of the world's great science workers with brief notes on their lives and achievements.

2. Pictures of scientific interest taken from journals like the *Graphic*, *Illustrated London News* and *The Times Educational Supplement*.

3. Pictures of such things as gas-works, power-stations, railway engines, aeroplanes and airships.

4. Maps showing sources of ores of metals and chemical products.

5. Cuttings from newspapers on matters of scientific importance.

6. Laboratory rules and regulations, and instructions as to procedure in case of accidents.

7. Weather-charts, maps and graphs prepared by pupils from actual observations or from data taken from weather-reports.

8. Samples of apparatus fitted by younger pupils can sometimes be exhibited, and also sample pages of notebooks of boys of lower classes.

Science Museum

A museum ought to be a very valuable part of science department. Nature study and chemistry furnish many examples of things which may be kept in a museum.

The museum should be scholar-built, i.e., the exhibits should be mainly the outcome of the efforts of the teacher and the pupils. As far as possible, ready-made purchased articles should be avoided. Inferior objects should not be accepted. It is a good plan to replace with better objects those that have with age or use become unsatisfactory. When it cannot add to its collections, a museum dies. Lost collections must, therefore, be reformed.

The museum should mainly consist of:

1. Dry exhibits like seeds, leaves, roots, weeds; specimens of ores and minerals; samples of products brought from places visited. These should be kept in bottles with neatly written labels giving the name of the article, of the donor, the locality and date.

2. Fish, snakes and water-weeds. Wet mounting is a skilled process. The objects are mounted in cylindrical jars with ground-glass stoppers; 10% formalin solution may be used for ordinary animals and 2½% for water-weeds. Rectified spirit can also be used but it is more costly. Methylated spirit is not good. The preservative should be changed twice or thrice and then the objects finally mounted and the jar sealed.

3. Butterflies, insects and shell-fish. These are exhibited in boxes with cork bottoms. Silver-plated pins should be employed to fix the objects for these do not rust. Naphthalene balls should be placed in the boxes to avoid danger from moths.

Besides these three main kinds of exhibits, the museum may contain models of mechanical devices made from meccano, specimens of local industrial products, models showing stages in the manufacture of articles like matches,

pencils, etc., working models of a steam-engine, telephone, motor, power-house, and apparatus made by pupils in the school workshop. Crystals prepared by pupils in the laboratory may also be exhibited temporarily.

First-Aid Box

In every laboratory there should be a special cupboard or a separate case for first-aid appliances, for accidents may happen and the teacher must always be prepared for emergencies. The cupboard should contain bandages, boric wool, lint, oiled silk, scissors, tincture of iodine, boric acid, sodium bicarbonate, carbolic acid, ammonia solution, spirit ammonia aromatic, karon oil (mixture of lime water and sweet oil), vaseline, iron perchloride, lysol, and a clean wash-bottle full of clean water. Pasted up by the side of the cupboard should be a list of common accidents and the remedies to be applied. This scheme should first receive the approval of the medical officer. Remember that first-aid is only first-aid. If the accident appears to be serious the help of a medical officer should be requisitioned.

IV. SPECIAL AIDS TO SCIENCE TEACHING

Visits to Places of Scientific Interest

EVERY science teacher should see that his teaching in the school-room has a relation to the larger things which are continually taking place outside the school. Visits to factories and works should form a part of every science course from the point of view of fostering scientific inquiry, for supplementing work in the classroom and laboratory, and for the development of local interest. Places such as a power-house, fire-station, soap factory, glass works, iron foundry and salt mine never fail to interest children. Some teaching should evidently be given before the visit by way of preparation. The amount of preparation necessary will, of course, depend on the age and technical knowledge of the pupils. The teacher should first visit the place himself in order to frame instructions as to what is worth seeing and asking for. The visit should be followed up by asking children to write accounts or answer a few simple questions.

In rural districts visits to farms, orchards and dairies should prove equally interesting.

The places visited will depend not only on locality but also on the subject studied. A class having a course in nature-study must have opportunities for studying nature at first-hand by means of visits to the country, or to ponds and gardens. A class studying chemistry will find visits to some types of chemical works equally beneficial.

Visits to museums, if one is available in the locality, should always be encouraged. Museums are generally organized from a simple educational point of view and a single visit is worth many theoretical lessons.

Some of the places of scientific interest to which such

visits can be planned are the telephone exchange, the radio station, botanical gardens, zoological parks, an airport, a sea-port, an observatory, water works, sewage-disposal works, and industrial exhibitions.

Pictorial Illustrations

Pictures of gas-works, steamships and locomotives, and portraits of great men of science — physicists, chemists, biologists and astronomers — will be of great help in science teaching if reference is made to them. Everything a child learns can be presented graphically with the aid of pictures and brightly coloured diagrams which will excite his interest.

Magic Lantern, Epidiascope and Cinema

A child grasps abstract facts slowly and can only remember a name which recalls some definite reality. He must be confronted with a sensuous experience and his curiosity and desire for knowledge should be aroused through striking images. Visual teaching broadens pupils' experience.

The magic lantern, the epidiascope and the cinema are important visual aids to science teaching. These are used for presenting pictures. The epidiascope is a more costly instrument but it can project opaque objects as well as transparencies. Moreover, the picture so projected is much brighter and needs a less powerful light so that the room need not be in absolute darkness.

Although a magic lantern with a good set of slides is a useful means of projecting pictures, the sub-standard cinema film is becoming increasingly popular. Its use is entirely free from danger for the films are non-inflammable. A white wall or a sheet can be used as a screen on which to project the pictures. It should be remembered that too long a show of film fails in its purpose.

Teachers should make a point of seeing each film beforehand, when they can make notes of special points to stress and unsuitable material to be run through very quickly. The use of sound-films as a teaching medium is hardly justified owing to the extra cost and trouble involved.

All schools cannot afford to buy the costly audio-visual aids mentioned above. Education departments of some States (Punjab, for example) maintain at divisional headquarters mobile cinema vans equipped with such apparatus. An electric generator too is carried in the van to be put into service in rural schools where electric power is not available. A qualified operator accompanies the van.

The Government of India maintains a library of educational films. Films can be had on loan from this library by any school for a specified term.

Broadcast Talks

Broadcast talks on educational matters by eminent scientists and other educationists are now a regular feature of the programmes of the B.B.C. and broadcasting companies of other Western countries. The B.B.C. broadcasts special seasonal courses in science for the benefit of school children. Pamphlets giving details of the course are prepared in advance and distributed to all schools. In India too, educational broadcasts are now a regular feature of the programmes of the All India Radio. A series of talks on the application of science to problems of everyday life will clearly be more effective and useful than a treatment of the basic principles of the subject.

The main handicaps in the way of success for educational broadcasts are:

1. The receiving apparatus is often not satisfactory and a sense of strain pervades the classroom.

2. It may not be possible to so arrange the teaching of the syllabus that broadcast talks and school work on the same topics come together.

3. Many children are poor listeners although they benefit by normal teaching of the subject through questions, demonstrations and reading.

In this connexion it is important to remember that these talks are not intended to replace the teacher but to help him in his regular teaching. Each talk should be of short duration so that the average child does not find it too tedious. Considerable further work by way of revision, demonstration and reading is necessary after the broadcast. It is only in this way that the talks can be really useful.

Gramophone Lectures

Records of short talks on interesting scientific topics by scientists, doctors and others are now available for use in the classroom, and science teachers should take advantage of them. Some records which will be found useful are:

(i) *How We Defend Ourselves from our Invisible Foes.* By Dr Fraser Harris. Parts 1 and 2 (Columbia D40088); 3 and 4 (Columbia D40089).

(ii) *Supply of Oxygen: Heart and Lungs.* By Professor A. V. Hill. Parts 1 and 2 (Columbia D40159); 3 and 4 (Columbia D40160).

(iii) *What is Sound?* By Sir William Bragg. Parts 1. and 2 (Columbia D40175); 3 and 4 (Columbia D40176)

The records were prepared by the Columbia Gramophone Co. Ltd. for the International Educational Society, Regent Street, London, W. 1.

Organization of Science Clubs in Schools

Such clubs, if properly organized, will be a great help in enlivening the teaching of science in general. They should be run by the pupils themselves with the teacher as chairman. A programme of regular meetings on Saturday afternoons (generally free in schools for this and similar

purposes) or at any other suitable time should be prepared. At each meeting short talks, the subject for which may be selected by the teacher or the pupils themselves, and simple demonstrations may be given by pupils and these should be followed by a discussion. Interesting experiments outside the class routine could well form part of the work of the clubs to enable students to develop skills and abilities for research work. Members of the club can make collections of specimens for the science museum, prepare charts, models and other exhibits for exhibitions and arrange excursions to places of scientific interest in the neighbourhood.

This scheme, besides stimulating interest in reading, gives a pupil who has a particular hobby or interest an opportunity to talk about it with the rest of the class. Topics which would not find a place in regular teaching can be discussed. In addition, the preparation of a talk by a pupil is in itself a great training for him in independent investigation and self-reliance. The atmosphere of interest that prevails at a meeting helps the teacher finally to round off the topic under discussion.

Science Fairs and Exhibitions in Schools

Functions like prize distribution, sports week or parents' day are a regular annual feature of most schools. Efforts should be made to hold an annual science fair or exhibition along with any of these. The school science club can be entrusted with this work. Interesting experiments, charts, working models of useful appliances, specimens collected by pupils during excursions, applications of scientific principles to everyday life, and scientific toys, can be exhibited at these fairs. This will give the pupils an opportunity to show their ingenuity and manual skill. It will create in them the habit of extra-study and provide a useful means of occupying their leisure.

Pupils should be told about the exhibition well in advance. Prizes in the form of general science books or merit certi-

ficates may be instituted and awarded for high class exhibits. Science club members may be put on duty to explain exhibits and show experiments to visitors.

The science teacher can utilize the opportunity for further instruction in science by holding discussions with pupils about the exhibits and the experiments shown.

V. SCOPE OF SCIENCE TEACHING

General

The school population in India can be roughly divided into three groups. The first group includes pupils up to the age of 10 or 11. This is the primary stage. The second group includes pupils up to the age of 13 or 14. This is the middle stage. The last group includes pupils up to the age of 15 or 16. This is the high stage.

Before the age of 10 or 11, boys and girls are not old enough for a formal training in physics and chemistry. The conception of science taught at this stage must not be falsified or distorted by an exaggerated importance placed on accumulating knowledge. Science lessons up to this age should, therefore, be confined to the study of nature in all its phases and of common objects and phenomena.

The course for pupils between the ages of 10 or 11 and 13 or 14 should consist of important topics taken from various branches of science like physics, chemistry, physiology, hygiene and biology, and treated in a general way. This course should not be merely a preliminary training in preparation for the high stage, because it will be the only course in science for those pupils who finish their education with the eighth class, and also those who continue their studies but do not take up science in the higher classes. It is important that the course should, as far as possible, be comprehensive and complete in itself. It should be sufficient to enable a boy to obtain some insight into science as a whole. Treatment on broad general lines is essential, and the adoption of the concentric method is advisable.

A systematic study of science starts at the age of about 13 or 14. Physics and chemistry will be the main subjects taught, and rightly so, for they form the foundation of all

other branches of science. Some attempt should be made to introduce contributions from other sciences, notably biology, which will make the boys realize that science consists of more than physics and chemistry.

In teaching physics and chemistry it should be remembered that the course must not be unduly academic. It is not uncommon to find principles being taught with little or no reference to the natural phenomena they explain. The course often appears to have been planned with the chief aim of serving as a basis for a specialized study later on. In planning the course, therefore, phenomena which are matters of everyday experience should not be ignored; the pupils' interest in the world around them should constantly be aroused and sustained. In physics all branches should be fairly represented, and in chemistry the distinction between organic and inorganic should be ignored, for there is a good deal in organic chemistry that can safely be included, and should be included, in any elementary chemistry course.

Teaching of Nature Study

Most young children come to school eager to learn. They are alive with curiosity, on edge to explore among other things the wonderland of nature, animate and inanimate. Nature study has rightly been an essential part of the curriculum of the primary school child. But unfortunately it has in too many instances meant largely a series of dictated notes to be learnt by rote rather than a real, vital contact with nature's wonders.

The object of nature study is to develop the child's sensitiveness and to make him feel at home with nature. The teacher's role is to create the proper atmosphere and to stimulate the interest awakened in any normal child by birds, butterflies, fishes and flowers. To do this the teacher should himself be interested in nature. He should develop his powers of observation and should cultivate a

love for animal and bird life along with a scientific understanding.

It has already been mentioned that up to the age of 10 or 11 boys and girls are not old enough to face the difficulties of a formal training in physics and chemistry and that the science course need include no more than nature study and some lessons on common things and familiar phenomena.

Nature study is the study of nature at first-hand in all its branches—plant, animal and physical; it is not a superficial or simple course of botany in which a few common flowers, plants and trees are studied in relation to seasons. It is an inquisitive, appreciative, and intelligent outlook on natural phenomena. It is not designed to produce naturalists. Its aim is to deepen the interest of the child in the world around him and to train him in the habit of careful observation and clear thinking.

The subject is important for these reasons:

1. It leads easily to later work in biology and other sciences.

2. It has practical utility in its relation to gardening and health.

3. It trains children to be observant, develops their reasoning power, educates hand and eye, and produces respect for life and a humane consideration for everything living.

A set syllabus should not be prescribed. The ground to be covered should be left to the discretion of the teacher and should vary according to the locality and the circumstances of the school. The course must be broad in aspect and include studies of plant and animal life and of natural phenomena like the sun, the moon, the weather, etc. Incidental lessons on recent events such as an eclipse, a flood or earthquake should find a place in the curriculum. General information lessons, for example, talks on making things of everyday use, like soap or butter can also be included. The subject must be planned along

lines that are vivid, free from formal tradition, quickened by enquiry, initiative and ingenuity and based on an appraisal of the essential needs and possibilities of the children themselves.

'The aim of the course should be to teach the children to make observations, to talk and write about what they observe, to acquaint them with the wonder and beauty of nature and with certain simple natural phenomena and processes, and to give them through this knowledge an appreciative love of nature and her ways.'[1]

Nature study should not be taught by object lessons. The child should be made to observe and handle each specimen, and encouraged under the guidance of the teacher to use his own reasoning powers about the subject of study.

The teacher must be practical throughout and keep along heuristic lines—asking questions and stimulating questions. The method of teaching should appeal to children's interest, rely less on mass instruction and more on encouragement of individual and co-operative effort.

The subject of study should be vitalized, so that it appeals to children.

Outdoor excursions should be a premier feature even if they have to be confined to parks and open spaces, and when material is used in the classroom it should preferably be living material. Living insects and small animals may be kept in school for certain periods under conditions of food and environment as near as possible to those in which they are found.

A seasonal method of treatment will be useful. Natural phenomena appropriate to each period can be thus dealt with. The relations between the weather, the condition of the ground, vegetable and animal life should be clearly

[1] Brown, John, *Teaching Science in Schools* (University of London Press), p. 76.

impressed, so also the interdependence of all living things—plants, animals, and man.

Visits to the zoo, the museum and the local nursery should be encouraged. Many valuable things can be learnt at these places.

Let young children learn how to use their notebooks. They should jot down their observations on the spot and make sketches. Future composition lessons can be based on material so acquired. In this way training in expression will go side by side with training in observation.

Solutions of practical problems can be expected from older pupils. Measurements of the various parts of a school garden will give a basis for mensuration and area determinations.

Experimental work will be possible in a school garden or even a small outdoor plot. Besides, pupils will get opportunities to make rockeries, pools and sundials. If a garden does not exist, plants should be grown in flower-pots and, if possible, botanical specimens should be displayed. Plants grown in flower-pots offer good opportunities for simple experimental work indoors — the effect of light on growth of plants, conditions favourable for germination, respiration and transpiration.

The collective instinct of pupils should be used in encouraging them to make collections of leaves, flowers and other specimens. These collections will lead to the growth of a school museum.

Teaching of Physics and Chemistry

From the classification we have given at the beginning of this chapter, it will be seen that physics and chemistry form the main portion of the science course for the middle and high classes. This is a sensible arrangement, for they constitute the basis of most of the other natural sciences, and their range covers many of the things man meets with in everyday life. It is necessary, therefore,

that every pupil should receive some instruction in physics and chemistry.

So far as the selection of topics for a science course from physics and chemistry is concerned, the teacher should see that he does not confine his teaching to one or two sections of these subjects. It may be necessary to study certain parts of some subjects in more detail, but this should not be done to the complete exclusion of the other parts. When such a necessity arises, a general course should first be planned so as to include, consistent with the time available, topics of most importance from all sections of physics and chemistry. This may then be followed, if necessary, by a more intensive course dealing with the special sections on more specialized lines for some particular purpose. The teacher should keep in mind the fact that only a small percentage of his pupils will continue their science studies in higher institutions, and he should so arrange the course that in the time at his disposal he is able to deal with the most important principles and applications of mechanics, hydrostatics, heat, sound, light, magnetism, electricity and chemistry.

Sometimes a section or a topic is apt to be ignored simply because it does not lend itself easily to experimental treatment. For the same reason, topics which require only easy measuring are apt to receive too much attention. This should not be so. General physics needs far more attention than mathematical physics or topics of mere academic value.

As regards the method of treatment the teacher should remember that though the course is broken up into conventional sections for the sake of convenience, the boundaries should not be stressed, and wherever possible illustrations from different sections should be given and discussed. In fact, he should endeavour to introduce illustrations and applications from all fields of science in order to broaden and humanize the subject.

Every opportunity should be taken to exemplify and illustrate principles from the facts of everyday life. A lesson on levers, for example, cannot be said to be complete if no reference to their use in agricultural implements is made. Similarly, when a lesson is given on expansion of solids by heat, reference should be made to (i) the fact that some space is left in the joint between two consecutive rails on a railway track, and (ii) the process of putting iron collars on wooden wheels of bullock carts.

The topic method is useful in teaching physics. Visits to generating stations are of great value in illustrating principles from the electricity course. Boys will be interested in comparing the production of electricity on a huge scale with the toy-production in the laboratory. Historical references in the development of a topic should be given by the teacher occasionally, and pupils should be encouraged to read the lives of great physicists and chemists like Faraday, Davy, Huxley, Sir P. C. Ray, Sir C. V. Raman and Sir J. C. Bose.

As regards chemistry, it should be treated very simply. The facts to be taught should be presented in the order of difficulty of comprehension rather than in a strict logical order. A logical order, however, must not be completely ignored. Historical references will be found interesting. Illustrations from everyday life and from technical processes should be frequent. A lesson on sulphur, for example, cannot be said to be complete without reference to its use in vulcanized rubber, gunpowder or in smoking out rat-holes; a lesson on phosphorus is incomplete also without reference to its use in the manufacture of matches, or to the use of its compounds in agriculture.

This question is often asked—should chemistry be taught before or after physics? In the Punjab the general practice is to begin teaching either physics or chemistry in the ninth class and the same subject in the tenth class,

and the next year the same practice is followed with the alternative subject. This method saves the teacher the labour of preparing two different lessons, as he can use the same apparatus and notes for teaching the same topic to both classes. From the point of view of education, a course of elementary physics should precede chemistry. Physics draws more abundant material from everyday life for illustration and so forms a better starting-point. All chemical experimentation, on the other hand, involves the observation of new physical phenomena, and in order to recognize these phenomena pupils must have had some training in the laws and principles of physics.

Teaching of Physiology and Hygiene

The science course for pupils in the middle stage, i.e., between the ages of 10 or 11 and 13 or 14, should provide for some instruction in the elementary principles of hygiene.

The course will naturally be simple and treated in a general, non-technical way. The teacher should try to avoid dull, formal lessons on isolated topics with rules and laws to be memorized for the purpose of an examination. Lessons in the form of talks and discussions are to be recommended. The pupils should be made to feel the whole time that the subject under discussion is of great importance to them. Simple experiments on respiration, the purification of water, etc., should be performed by the pupils as well as by the teacher.

As regards the topics to be included, the following may be considered as sufficient:

Water—Sources; properties; purification for domestic purposes; uses.

Air—Two chief constituents; properties of oxygen; importance of nitrogen in the atmosphere; impurities in air; ventilation; carbon dioxide; respiration and circulation; uses of green plants.

Food and Drink—Uses; importance of healthy food; chewing of food; digestion; temperance.

Diseases—A few common infectious diseases; disinfection; malaria, plague, etc.

Personal Hygiene—Cleanliness of eyes, ears, teeth, etc.; clothing; exercise; sleep.

For boys between the ages of 13 or 14 and 15 or 16, i.e., the high stage, this subject is not included as a part of the science course but stands as a separate one in a group of elective optionals. The course is prescribed by the examining body and includes practical work as well. Sometimes the science teacher is called upon to teach the course and sometimes a local medical man is engaged as a part-time teacher. The latter may be a capable man but not necessarily a teacher. A science teacher, if he knows the subject, is preferable because he is in touch with the pupils the whole time.

A few points for the guidance of the teacher of this subject are given below:

1. Besides teaching the prescribed course, certain interesting thing of common interest may be referred to on appropriate occasions. For example, muscular and tissue repair after injury should be mentioned during a lesson on the muscular system, and the process of nerve regeneration during a lesson on the nervous system.

2. Pupils should learn that the human body is a combined physical, chemical and biological laboratory, and they should never lose an opportunity of finding applications of these sciences to bodily health. In fact, such parts of the subject as come within the domain of physics and chemistry may be left to the science teacher.

3. General talks on social applications of modern hygiene and on village sanitation and public health should form part of the course.

4. Many cinema films of 16 mm. are available for hygiene teaching. They should be made use of.

5. An account of great workers—Jenner, Pasteur, Lister, Ross—who laboured to reduce the suffering of humanity must be included.

6. The story of man's endeavours to combat disease may be correlated with history and geography—leprosy and plague in the East, scurvy on long sea-voyages, healthy and unhealthy parts of the world, tropical diseases, malaria and the Panama Canal.

General Science

Plea for its Inclusion in the School Curriculum

For some years physics and chemistry have been the chief science subjects studied in secondary schools. It has, however, been urged for some time that the range of school science courses should be extended, particularly in the field of studies of plant and animal life. The principle is generally accepted that the outlook of school science should be extensive and not specialized or intensive. Biological subjects must be included. It is not an ideal plan to keep the three subjects, physics, chemistry and biology, in separate compartments. They should be incorporated into one whole course, the general science course.

The inclusion of this subject in the school course is also important from a utilitarian point of view. The study of science is useful both for the community and for the individual. The prosperity of a nation depends to a great extent on the presence in it of highly qualified technical experts and though it is not the function of a school to prepare such experts, their pre-preparation is certainly one of the chief duties of the school. It is at school that particular talents are discovered and their development encouraged. The syllabus should be broad enough to allow full play to the latent faculties of the child. The narrowness of teaching at school has very often been responsible for the failure to discover special

talents in pupils. If all pupils are given some idea of the many ways in which science enters our lives and alters our occupations, as members of the community they will be better able to appreciate the advice of science specialists and experts.

Again, science helps the individual in two ways, by enabling him to earn his living, and by training him to discharge the duties and carry on the activities of his ordinary life more efficiently. The first of these objects will suggest a specialized rather than a general course at school. The aim of secondary education is not to give a vocational preparation to pupils, nor can a school cater for more than a limited number of the diverse occupations open to members of the community. The opportunities of using scientific knowledge in daily life, however, are rapidly increasing in number. A knowledge of science will help the individual in carrying out his daily duties much more efficiently. Some knowledge of biology, for example, may help towards better and more healthy living.

The study of science leads to accurate observation, systematic reasoning and clear thinking. It is the duty of all concerned to help in a wide diffusion of these very desirable qualities, and for this reason a narrow curriculum is to be avoided. The child must not get the impression that science is merely a formalized study which has no direct application to things around him.

The strongest of all claims for the inclusion of science in the school curriculum is the cultural value of the subject. No one can be considered truly cultured if his imagination is not stirred by the scientific explanation of natural phenomena in the world of today. Children are very inquisitive about their environment. Natural science, therefore, makes a special appeal to them. All educationists should take advantage of this opportunity, which the children themselves offer, to teach them the things they are eager to know.

Construction of Syllabus

The science course should be designed to cover a wide range, and the natural curiosity of pupils about their environment should influence the choice of topics in the syllabus. Briefly, the following points should be kept in view when drawing up a syllabus:

1. The subject must interest the pupils, for if we try to teach them the things they want to know, they will be eager to learn.

2. Every item in the syllabus should lead to an understanding of fundamental principles; an intellectual understanding of isolated phenomena is impossible without an understanding of the principles which unite them. It should, for example, be shown how structures, functions and processes in plant and animal life have many relationships in common. A knowledge of these aspects of science is regarded as essential in every course of general science.

3. Any teaching which fails to produce in the learner the habit of perseverance, an independent approach towards the solving of problems, and the application of previous knowledge is uneducative, however much information it may succeed in imparting, for the educative value of a subject exists not in the subject alone but also in the way in which it is studied. The syllabus should provide a field suited to the cultivation of these habits.

4. Before deciding upon the amount of material to be included in the syllabus, it is necessary to take into consideration the time which is to be devoted to the subject.

A copy of the general science syllabus prescribed in West Bengal is given in Appendix II to this book. This will be a useful guide to teachers wishing to frame a syllabus themselves.

A syllabus in general science and everyday science for the primary and middle classes respectively recently prescribed in the Punjab is shown in Appendix I. The difference lies in the fact that while general science is included as

such in the School Final examination in West Bengal, it is not included in the Matriculation syllabus in the Punjab.

The Bombay syllabus includes elements of physiology, botany, zoology and hygiene in addition to those of physics and chemistry, the main idea being to provide an elementary knowledge of a wide range of subjects rather than detailed or specialized training in one particular branch of science.

Method of Teaching

A syllabus at best is a particular arrangement of facts. For its true worth and vitality it must depend on the use made of it by the teacher. In the past the syllabus was interpreted too rigidly. This has to be avoided at all costs in the case of a subject like general science.

The old didactic method is of little use in teaching this subject. It is ineffective in developing a boy's powers or in making him love his work. It lacks an element of inquiry and a spirit of discovery and research so essential to science. The pupil is not faced with a problem and his work, therefore, lacks incentive and is not done in a spirit of active co-operation. The problem method is extremely effective. The lesson is started by reference to some familiar application of the principle to be taught. Discussion leads to a particular problem, and suggestions are invited from the class as to how it should be solved. The results are gathered together into a general solution. One important caution may be mentioned. Under the old methods matter was considered to be more important than method, while the modern tendency is to sacrifice matter to method. This has to be avoided, for the study of science involves the consideration of a definite and chosen range of material. Children should not only learn science but should also learn to love it.

It is important to keep in view the interests of children at various stages. Young children are more interested

when the facts presented are in themselves wonderful and extraordinary; at a later stage of their development they like to study topics useful in the world of practical affairs. Logical and formal teaching in the early stages should be avoided, and much of the work should be done in a way commonly called popular. Matters of interest may be followed up as they arise, whether they strictly come within the boundary of the subject or not; but it is unwise to attempt to teach too much as an over-intensive treatment kills interest in a subject. Topics should be illustrated profusely by examples from daily life.

It is advantageous in the early stages to entrust all the science teaching to the same teacher, even if he does not profess to be expert in every branch of the work.

The course should include a certain amount of history of scientific interest. Biographical details of the lives of great scientists help to introduce a most desirable human element. There should, however, be no formal instruction in the history of science. This should be reserved for occasional treatment by the teacher, for discussion in the boys' science club, or for individual reading.

Quantitative experiments of mathematical examples have little room in a general science course and though these cannot be banished altogether, they should be greatly reduced and the calculations set should be arithmetically as easy as possible, for the primary aim is to teach science and not arithmetic.

Teaching of Biology

Biology forms an important part of the syllabus of general science—a subject which is now compulsory for all students preparing for the Higher Secondary School Examination. While the basic principles of teaching sciences apply equally to the teaching of biology, there are certain special points which the teacher of biology will do well to keep in view.

1. The subject should not be taught merely by object

lessons. Living materials should be used in the classroom as far as possible. Nature should be shown as a complete whole. Natural relationship and interdependence of life must be maintained.

2. Pupils should handle each specimen in order to observe things for themselves. They should be encouraged to think, to reason and to draw inferences from what they observe. Every school professing to teach this subject should, therefore, possess a small aquarium, a vivarium and a garden plot. Pot-plants, caged birds, insects and botanical specimens will prove helpful when schools are situated in big cities where it may not be possible to acquire a plot for the school garden.

3. The teacher should illustrate lessons with experiments and encourage pupils to perform simple experiments themselves. They can, for example, grow some plants and study for themselves the conditions favourable for germination etc.

4. Excursions to the countryside, local gardens, parks, nursery, natural history museums, and the zoo must be encouraged to give pupils an opportunity for getting first-hand information. The teacher should guide their observation and they should be encouraged to put questions and cross-questions.

5. While out on an excursion, pupils should collect flowers, leaves and other natural history specimens. These can later be placed in the school science museum.

6. Outdoor work must be supplemented by class demonstrations to stress important points. Pupils should be required to write out accounts of what they observed, and encouraged to draw diagrams. They should be asked to hunt out information regarding their observations from library books. The teacher can assist them in this task by suggesting the names of a few useful books present in the school library. This would stimulate the habit of reading books other than the prescribed textbooks.

Films can be used very profitably to impart information

and illustrate points that would otherwise be difficult to explain.

7. General science may be said to be science in action in day to day life as distinct from memorization of book formulae at the higher secondary stage. It is, therefore, essential that lessons in this subject should be closely connected with the daily life of pupils and with their environments and surroundings.

8. General science should not be treated as a collection of topics from different sciences but should be taken as a whole. Biology should not, therefore, be taught in isolation from other branches of science but in correlation and co-ordination with them.

VI. CURRICULUM IN THE PUNJAB

Primary Classes

AT the present time the primary course in the Punjab is a five-year one. Till 1950 only nature study and no other science was taught in these classes. According to the revised curriculum of 1950 general science is one of the subjects to be studied by every pupil in classes I to V. The syllabus in general science includes personal hygiene, sanitation, elements of plant and animal life, elementary study of air, water, food etc. The subject aims:

1. To give pupils an intelligent and appreciative outlook on nature.

2. To encourage pupils to observe things around them and test their observations by experiments, thus stimulating in them the spirit of scientific inquiry.

3. To enable them to understand the scientific principles exemplified in the natural phenomena around and the application of science in the service of man.

4. To introduce them to the important incidents in the lives of some great scientists.

In addition, there are three other main subjects—the mother-tongue, a second regional language and arithmetic. A Basic craft (agriculture or spinning and weaving), health and social activities, social studies and recreational activities including physical education are the other subjects prescribed for the primary classes under this new scheme of 1950. The syllabus in general science for Class I-V under this scheme is given in Appendix I.

Middle Classes

The scheme of science prescribed for the middle classes till 1950 was called the Rural Science Scheme. It was over-biased in favour of agriculture. This scheme did not prove popular as teachers with the requisite qualifications were

not available, nor were all schools in a position to afford the necessary apparatus and provide agricultural farms. This scheme was replaced in 1950 by a new curriculum in which Everyday Science took the place of Rural Science and the subject was made compulsory for all pupils. The syllabus in Everyday Science consists of topics drawn from physics, chemistry, agriculture, hygiene, sanitation and human physiology. It is given in Appendix I.

It will be seen that the scheme of 1950 brought about a great improvement in the position of Everyday Science in the general scheme of studies for the primary as well as the middle classes in that the subject was made compulsory for all pupils. It should also be noted that the 1950 scheme of studies for classes I to VIII applied equally to boys' and girls' schools.

The syllabuses prescribed in general science for primary classes and in Everyday Science for middle classes in 1950 are now being replaced by a new syllabus in general science for Classes I to VIII. This is given in Appendix I. This is the outcome of an effort to give some sort of technical bias to education of children from an early start while keeping it broad based at the same time. A study of the scheme of 'Practical Work in General Science and Workshop Projects for Classes VI to VIII' (Appendix I) will reveal the technical bias sought to be given to the syllabus in general science for these classes.

High Classes

The syllabus given in Appendix I is prescribed by the university. A perusal will show that this syllabus is divided into four parts—theoretical chemistry, practical chemistry, theoretical physics, practical physics. This division gives a wrong idea of science as a whole. Some teachers regard the practical part as an entirely separate entity and finish the theoretical portion before starting the practical work. This is a wrong procedure as has already been pointed out. More-

over, some teachers do not like to go beyond the prescribed minimum in practical work. The course is so simple that nearly the whole of it can be done by the pupils themselves except for those experiments which are dangerous or require expensive apparatus. To pass the Matriculation examination in science it is compulsory to pass in practical work and theory separately by securing 25 per cent and 33 per cent marks respectively and also in the total of both by securing 33 per cent marks. Practical work carries 40 out of 150 marks for the total.

A new syllabus for the Matriculation examination is being prepared by the Punjab University. According to the new syllabus, general science will be one of the five compulsory subjects. General science will include elementary biology, hygiene and physiology. Physics and chemistry will be optional subjects.

The syllabus and scheme of studies for the primary and middle classes in Delhi follow more or less the pattern of the Punjab.

Basic Schools

The syllabus in general science for Classes I-V of Basic primary schools suggested by the Basic National Education Committee is given at the end of Appendix I.

The Committee rightly observe that the development of a scientific attitude of mind should be our main objective at this stage. Village life affords ample opportunities of developing this. The teacher should try to utilize the rich life of nature around the child, the daily agricultural activities, animal husbandry and handicrafts in the village to develop the child's power of observation, questioning and experimentation. For children of 5 to 9 the objective will be the establishment of right habits and attitudes rather than the giving of information.

Higher Secondary Classes

The problem of reorganization and improvement for

education at all levels has been before the country for many years. In 1948 the Government of India appointed the University Education Commission under the chairmanship of Dr S. Radhakrishnan. The commission in its report observed 'that before graduation there should be only one public examination and that at the Intermediate Examination stage. This examination should mark the end of secondary education and the beginning of university education which should extend over a period of three years for the first degree course'. Further, 'that the standard of admission to the university courses should correspond to that of the present Intermediate Examination, i.e., after the completion of 12 years of study at a school and intermediate college.'

On the recommendation of the Central Advisory Board, the Government of India appointed in 1952 under the chairmanship of Dr A. L. Mudaliar, a Commission to suggest measures for the reorganization and improvement of secondary education. The Commission recommended that after 8 years of elementary education (5 years of primary or junior basic and 3 years of middle school or senior basic) there should be a 4 years' diversified higher secondary course in which provision should be made for students to select subjects of study according to their special aptitude, the local environment and the needs of the community.

In making the above recommendation the Commission was obviously influenced by the fact that the prevailing system of secondary education leans heavily to one side. It is predominantly academic in character and its chief purpose is to secure entrance to a university. It does not cater for different aptitudes and interests or for the economic needs of the country. Secondary education should not only enable the students to enter a university if they so choose, but also enable them to take up a definite vocation. The Commission therefore suggested that a certain number of subjects, called 'Core Subjects', should be studied by all students. The core subjects should include (1) language, (2) general science,

(3) social studies, and (4) a craft. In addition, every student should take up a special course, that will make him competent to take up a definite vocation in later life. The elective courses suggested by the Commission are (1) Humanities, (2) Science, (3) Technical Subjects, (4) Commercial Subjects, (5) Agricultural Subjects, (6) Fine Arts, and (7) Home Science.

It will be seen that the really important feature of the multipurpose Higher Secondary Scheme is the diversification of the courses, giving opportunity to students to select a group of related subjects for study according to their aptitudes and the needs of the community.

Many states have substituted the Higher Secondary School Examination for the Matriculation Examination at the close of secondary education. Others are following suit. The Punjab University introduced the Higher Secondary Scheme in 1958. The Matriculation Examination, however, is for the present being held side by side with the Higher Secondary Examination to cater for the needs of pupils of those high schools which have yet to be upgraded to the higher secondary standard. The duration of the higher secondary course is of three years and not four years as suggested by the Commission for it is not immediately possible to have a four years higher secondary course. That would be expensive and it may not be possible to find sufficient number of qualified teachers to raise all high schools in the state to Intermediate level.

General science is an important core subject for the Higher Secondary Examination and is compulsory for all students. The syllabus prescribed for this subject by the Punjab University is given in Appendix I. Special care has been taken in drafting this syllabus. Not only have the subjects for study been indicated, but also information has been given about the demonstrations that students should see the experiments they should perform and the excursions they should make.

General science is viewed here as science in everyday

life; it is science regarded as a whole and in one group, not as separate subjects. The syllabus consists of a number of units around which different sciences are integrated. The course content indicates broadly how the approach can be made.

The course content might appear rather heavy, but it is understood that the treatment of the various topics will only be of a general nature and not exhaustive. It is, however, essential that a large amount of practical work be organized in connexion with this syllabus. The emphasis should be on the common experience of pupils. The syllabus should be built as far as possible round such experiences and highlighted by class demonstrations. Science club activities should play an important part in general science education.

While general science as one of the core subjects is compulsory for all, candidates wishing to specialize in certain branches of science can do so by taking up these branches as part of the elective science group from the seven elective groups mentioned above. This group comprises Physics, Chemistry, Biology, Geography, Mathematics, Physiology and Hygiene (not to be taken with Biology) and Higher English. Any four subjects can be chosen from these seven.

The Government of India has under consideration a scheme for the establishment of four regional colleges to train teachers for the practical needs of the multipurpose schools. These four regional colleges would have an intake capacity of 200 per institution to train teachers for technology, agriculture, science, commerce, home science, fine arts and crafts.

VII. THE PLACE OF SCIENCE IN GIRLS' SCHOOLS

THERE can be no adequate excuse for the omission of the teaching of physical science to girls. Apart from the fact that it is an important element in the general culture of an individual, a knowledge of physical science is clearly essential for girls in view of some of the professional careers now open to them. Whether they become teachers of science, teachers of domestic subjects, doctors, dentists, welfare-workers or health-visitors, a knowledge of the elementary principles of physics and chemistry is an absolute necessity.

Physical science was included as one of the subjects in the scheme of studies for girls' schools, but it was not popular or well taught. This was due to the indifference of pupils' parents to the subject, the lack of proper equipment and suitably qualified women teachers, and the supposed difficulty of learning it. As, however, the importance of physical science to the various professions to which girls are now being called in greater numbers is being realized, the subject will find its proper place in the education of girls, and equipment and the methods of teaching are bound to improve.

The subject which was hitherto more popular was domestic science. This included a course in cookery, laundry, household-management, etc. It was not a part of the science course but was taught as an independent subject. In the Punjab it is taken up as a compulsory subject in place of mathematics (if the girl so desires) to pass the Matriculation examination. In that case, domestic arithmetic forms a part of the subject. It may also be offered as an elective optional subject without arithmetic by girls who otherwise offer mathematics as a fixed compulsory subject.

The true aim of teaching science is often lacking where the subject is taught; too often detached facts are taught by way of imparting knowledge and information. It is time that the subject was given a scientific basis, for, after all, every intelligent woman who runs a household ought to know the underlying principles of most of the processes and happenings in her daily environment. House problems would then no longer be rule-of-thumb affairs but would be dealt with by the application of known principles of science.

The science teacher and the domestic science teacher should co-operate, for the science teacher can explain and demonstrate the principles underlying the processes which the girls learn under the direction of the domestic science instructress.

As regards the topics which should find a place in the course, the following will be found useful:

Water—Sources; composition; purification for household purposes; town water-supply; hard and soft waters.

Air—Composition; impurities; ventilation; purification by natural agents; carbon dioxide; green plants.

Food and Drink—Uses; kinds; various methods of cooking and preservation; milk—its importance and preservation; determination of its density; disposal of sewage and refuse.

Home-nursing—Preparing invalid food, poultices, hot water applications; care of bed; solutions and solvents—water, benzine, turpentine, petrol, etc.

Soap—Preparation; kinds; uses.

Chemistry of the Kitchen—Nature and action of alkalis and acids; sugar; salt; baking-powder; starch; flour; yeast.

Clothes—Washing; removing stains; simple dyeing.

Heat—Thermometer; temperature of boiling water; thermos flask.

Disinfectants, etc.—Boric acid; boric wool; lint; carbolic acid; ammonia; caustic soda; potassium permanganate; etc.

VIII. MISCELLANEOUS POINTS

Lesson Notes

The notes must be brief. They should contain:

1. *Apparatus*—A list of the apparatus required for demonstrating the topic under discussion.

2. *Aim*—This must be stated in clear, definite, unambiguous words. The aim must dominate the lesson, i.e., all points dealt with in the lesson must have a bearing on the aim, and the aim must be accomplished or the lesson will be a failure.

3. *Previous Knowledge*—Note the stage to which the class has progressed in the subject. This provides the basis of the lesson about to be given.

4. *Development Stages*—The object of each stage in the lesson should be mentioned briefly, and the nature of the questions to be asked should be indicated by giving one or two examples. The art of interrogation is of paramount importance in any successful lesson, but the questions will fail if they are ambiguous or lead nowhere in particular. Each stage will have its blackboard summary and this should be shown. The *introduction stage* is devoted to testing previous knowledge. After this is done, the scope of the new lesson is given in a short statement. The *presentation stage* consists of teaching the new lesson by means of experiments. Then comes the *formulation stage* when the principle taught is arrived at after reasoning it out with the class from the facts observed. The *application stage* follows; this is for demonstrating how the principle under discussion can be applied to matters in everyday life. Lastly there is the *recapitulation stage* when a few questions are asked to test if the new knowledge imparted has been understood and linked with previous knowledge. A statement of illustrations and pictures to be shown, or experiments to be performed, is

given under every stage. The experiments need not be described in detail but a sketch may be drawn on the right-hand side of the notebook and a reference made to it in the notes.

5. *Blackboard Summary*—A complete list of all blackboard summaries which will be used during the lesson should be given at the end of the notes.

Scheme of Work

The science syllabus prescribed by the university or the Education Department does not pretend to be anything more than a collection of topics on which questions may be asked in an examination. The work of arranging these topics in an order in which they can be discussed in class is left to the teacher. The preparation of a satisfactory teaching syllabus is not easy, especially if full justice is to be done to the questions which may be set in an external examination. The best way for the teacher to prepare a teaching syllabus is to go through the prescribed syllabus and get a general idea of its scope. He can then draw up an independent teaching syllabus of his own, logically arranged in such a way that all gaps in the examination syllabus are filled up, principles are established, points of theory are worked out, and applications to daily life are included. There is a natural sequence in the selection of successive topics which should not be ignored. Questions may not be asked in an examination on the subject-matter necessary to fill the gaps in the examination syllabus. Nevertheless it should be taught, for it is essential to the rational development of the subject.

The next stage is the quarterly and weekly distribution of this syllabus. Common sense and hard work are all that is required for this part of the work. Some teachers feel that such a scheme is useless, because, for unforeseen

reasons, it can seldom be carried out. This is no reason for working haphazardly. Moreover, a detailed scheme will indicate how much work has to be made up in cases of unforeseen delays.

When drawing up a scheme for distributing the work in the syllabus the following points should be considered:

(i) the number of periods a week for class work
(ii) what holidays are gazetted
(iii) what local holidays are likely to be given
(iv) how many lessons will probably be dropped for such reasons as house examinations, sports days, etc.

If there are four periods a week for classroom work, arrangements should be made for three only throughout ordinary weeks, the one remaining to account for unforeseen omissions. If in certain weeks there are no interruptions, the fourth periods can be utilized for making up deficiencies, giving tests, revisions, etc. The details of the syllabus, together with any subsidiary lessons that appear to be useful, are allotted dates. Care has to be taken that too much is not attempted. The scheme should be drawn up in this form:

Week	*Date*	*Subject*	*References*
1st	2-4-62	I. Matter and general properties	pp. 2-3
	3-4-62	II. Divisibility and porosity of matter	pp. 3-4
	6-4-62	III. Compressibility and elasticity	pp. 4-5
2nd	9-4-62	I. The three states of matter	pp. 6-7
	10-4-62	II. The character of solids and liquids	pp. 7-10

As regards practical work, it should be a little behind the classroom work, say a fortnight, because by that time the teacher will know how much of a lesson given in the

classroom has really been assimilated. Practical work is also an excellent form of revision.

The Science Teacher, his Time-table and Diary

The success or failure of a science course rests mainly with the teacher. He may be given a first-class laboratory and equipment, an ideal syllabus, and an ample time allowance on the time-table, but unless he is enthusiastic about his work, knows the subject, and really knows how to teach science, he is not likely to achieve success. A keen well-informed teacher who loves his subject and believes in its value will succeed in spite of difficulties and handicaps.

As regards the academic qualifications of science teachers in the Punjab, it is usual to find a teacher who has passed the Vernacular Middle examination and taken a one year or two years' course of training in a Normal school (and become a Junior or Senior Trained teacher) teaching science to the middle classes. These teachers are handicapped in two ways. Their background of knowledge is shallow; in most cases it does not go beyond the Vernacular Final syllabus and whatever they have managed to pick up at the training institute. They also lack a knowledge of English which precludes them from making more progress and bringing their knowledge up to date, for good books on general science or science teaching are to be found only in English. If matriculates are admitted to the vernacular training institutions, these handicaps will be removed to a great extent. (In the Punjab, the minimum qualification for admission to the J. T. Course has now been raised to the matric standard, and a J. T. with a minimum teaching experience of 3 years is admitted to the S. T. Course.)

A trained B. Sc. is usually in charge of science teaching for the high classes. This qualification should be considered sufficient, but instances are not lacking where a

B.Sc. or a M.Sc. fresh from college, without any instruction in the method of teaching science, is put in charge of science teaching in a high school. The Education Department, however, is making it more and more obligatory on grant-aided secondary schools to employ trained teachers for teaching all subjects. A trained M. Sc. is required for the Higher Secondary Classes.

Trained science teachers, in common with other teachers, require the stimulus of a refresher course. In order to keep themselves abreast of the latest methods of teaching science and refresh their knowledge of general science, to be able to see some of the latest books and apparatus concerning science teaching, and obtain instruction in arts and scientific hobbies, such courses, which should occasionally be arranged at a central place such as the training college, are a necessity. Other ways of keeping in touch with modern developments and movements include visits to schools where science is successfully taught by new methods, membership of a good science association, if one exists, and membership of a good library containing books on general science and methods of teaching.

As regards the time allowance, two lessons of about half an hour each per week should be sufficient during the nature study or primary stage. For the middle stage three periods of 40-50 minutes per week should be enough; at least one of these periods should be reserved for practical work by pupils. For the high classes a minimum of three hours per week should be allowed.

In the Punjab the common allotment in a high school is six periods of 40-50 minutes per week, which includes practical work. The total amount of time devoted to science is satisfactory, but the proportion of lecture work to laboratory work requires some consideration. In some schools the whole of the available time is spent on lecture work, practical work being taken up in the evening or after the theory is finished. In others, four periods are

spent on theory and two on practical work. A reverse allotment would be educationally more sound, i.e., four periods for practical work and two for lecture work. The four periods for practical work may be turned into two double periods of an hour and a half each.

The conservatism of the average science teacher in this matter of making classroom work predominate is due to the fear that examination results may suffer; his average percentage of passes for years has perhaps been reasonably high and he feels that experiment is dangerous. It is strange that the science teacher, above all, should be chary of experimenting. The fault is not entirely his; the headmaster, the education authorities, and the public demand good results in examinations, and a teacher's reputation and promotion are frequently dependent, in a great measure, upon the examination results of his classes. However, the science teacher should not shun experiment within reasonable and safe limits. He should realize that boys learn best by doing things themselves, and the teacher who tries the experiment of giving more time to practical work will undoubtedly find that his results will not suffer but will, indeed, improve.

Next comes the question of placing these periods in their proper order in the time-table. Classroom lessons do not call for any special place in the time-table provided a free period before the lesson has been allowed to the teacher for preparation of experiments. As regards the periods for practical work, they should be placed at the end of the morning or afternoon session so that, if occasion requires, a few minutes extra may be taken. A teacher should not make a practice of detaining his class, especially when the following period is in charge of another teacher.

If, instead of having two double periods for practical work, we have one double period and two single periods for this work and two single periods for classroom work

the science teacher's time-table may be drawn up on the following lines:

Days	First period	Second period	Period just before recess	Recess	Last but one period	Last period
Mon.	Preparation	Demonstration X				Practical IX
Tues.	,,	,, IX				,, X
Wed.	,,	,, X	Practical IX			
Thurs.	,,	,, IX	,, X			
Fri.					Practical IX	
Sat.					,, X	,, IX ,, X

In the majority of schools in the Punjab the number of pupils taking up science does not exceed 40 in each of the two high classes. They can be taken together for a demonstration and can be divided into two groups of twenty for practical work—not more than twenty pupils can be effectively supervised. The question arises as to what the second group is to do while the first is engaged on practical work. There are usually so many alternative subjects offered by candidates for the matriculation examination that the whole of a group not employed in the science laboratory cannot go to study one and the same subject elsewhere. In such cases the remedy lies in providing more accommodation and more staff, or in limiting the number of alternative subjects taught. There should be definite science and classical combinations. If these alternatives are not possible, the second group of science pupils can be made to sit in the laboratory and do the preparatory part of the next assignment, or answer a few questions on class work. This is one of the advantages of adopting the Whitehouse plan of a combined lecture

room and laboratory. On this system each boy will get half the number of turns for practical work provided for in the time-table. To make up the deficiency, two extra periods of practical work a week will have to be given in the evening.

It is difficult, perhaps inadvisable, to lay down the maximum number of periods a science master should be called upon to teach. A great deal depends on the size of classes, since the amount of correction work and the preparation for practical work will vary according to numbers. In the Punjab a science master, according to the Punjab Education Code, is required to teach 27 periods per week. These, with six periods for preparation work, make 33 periods. Work done after school-hours should be counted when estimating the number of periods per week.

A science teacher is frequently called upon to teach subjects other than science. When this is necessary, mathematics appears to be the most likely subject, but he should not be asked to teach English because of the great amount of correction work required in this subject.

A science teacher's time-table should not only contain the periods allotted to classroom and laboratory work, but should also show the periods devoted to preparation, and the cleaning and upkeep of apparatus. If such items are entered, there is much more likelihood of the work being regularly carried on.

A science teacher should keep a diary in the same way as other teachers. It should show the syllabus which he has drawn up, and particulars of the quarterly and weekly distribution of work, together with a copy of his time-table. A record of daily work should be entered daily and dated. This record should show what parts of the proposed work for the day have been accomplished, what parts have not been covered, and what extra work has been attempted. Details of written work, questions set, and advice given

on study should be entered. Comments on assignment work and practical work, and hints as to method and experimentation and difficulties which may be encountered, should be noted. It is also a good idea to make a note of general mistakes found in the pupils' work, so that the teacher will remember to explain them to the whole class. The diary may also contain results of house examinations or weekly tests. A record of apparatus or chemicals to be ordered may be also kept, for it is often found that want of a piece of apparatus is felt during a lesson but is forgotten when an order is being placed at the beginning of the year.

The entries which relate to the proposed day's work should be made before the lessons begin; after the day's work is finished the teacher can then enter the other notes on lessons mentioned above.

Textbooks and Laboratory Manuals

A good textbook is a source of knowledge arranged systematically. Its value lies in the fact that it enables pupils to acquire the needed information speedily. But the teacher should not be under the impression that he can teach his subject successfully by transferring the contents of the textbook into the heads of the pupils, for even the best book omits details which he has to supply. In the high classes, pupils use their textbooks for the preparatory part of an assignment, and for revising the subject in a systematic form after the course is finished. If the work is not conducted on the assignment system, pupils use their textbooks to study at home after a demonstration has been given by the teacher. A number of books are generally prescribed by the university or education authorities and the teacher has to select for his pupils the one he thinks best. In his choice he should be guided by the following points:

(i) Correctness of matter, and in this connexion the

standing of the author and the reputation of the publishers should be taken into account.

(ii) Purity of language.

(iii) Simplicity of diagrams.

(iv) Quality of printing and binding.

The use of a laboratory manual, unless good, should be avoided. If the work is being conducted on the assignment system, each pupil should possess a copy of Dr Whitehouse's book on assignments[1], and follow it when doing practical work. If any other system is being followed, the teacher should draw up a scheme of practical work, as he does in the case of theoretical work, which will give pupils:

(i) directions for fitting up the apparatus

(ii) precautions in performing the experiments

(iii) methods of recording results

(iv) a list of experiments to be performed.

The printed laboratory manuals generally give too many details and so make the work more or less mechanical, and pupils waste a good deal of time in reading and understanding them. They are often merely a collection of hints about the various experiments demanded in the university syllabus without any attempt to link them up to form a systematized whole.

Notebooks and Note-taking

Every boy is expected to have three notebooks, the first for the preparatory part of assignments, the second for taking down blackboard summaries and notes of demonstration lessons, and the third for practical work. The first two may be blank or ruled as the pupil wishes, but the one for practical work must be blank. These notebooks may have three different colours, blue, green and pink, or any others, but the teacher should insist on uniform note-

[1] Whitehouse, R. H. and Mabel, *Assignments in Practical Elementary Science for Matriculation Classes* (Macmillan).

books being used throughout the class. All notebooks should be kept as clean as possible. The writing should be done on the right-hand page, the left-hand page being left free for corrections, diagrams and calculations, and for further notes from new textbooks, library books, or revision lessons.

Some teachers prefer to use printed notebooks. As a rule they should be avoided in the high classes, for here pupils should learn to make notes on their own initiative without the help of printed notebooks. So far as the middle classes are concerned, printed notebooks are a help. The time at the disposal of the boys or the teacher is not enough and so a good deal is saved if the notebooks provide columns for recording results, the name of the experiment, and also a list of the apparatus required. Moreover, boys at this age are mere beginners and do not know how to record an experiment properly. Care has to be taken by the teacher in the selection of the proper notebooks. Some notebooks in the market are written by people with no experience of schools and they expect far too much in the way of experimentation as well as equipment.

Note-taking is an art, and boys cannot be expected to take notes unless they have acquired this art by practice or learnt it from the teacher. In the lecture room, no matter how slow and deliberate a speaker he may be, the teacher says a good deal more than the pupils can take down; they cannot discriminate between essentials and non-essentials and may lose the train of thought. It is advisable for boys to copy the teacher's notes from the blackboard. These notes, as pointed out before, are in the pupils' own language, corrected where necessary, and if they are copied the teacher knows what his pupils have written, and in what order, which will save him much time in correcting.

The *homework* in science will generally consist of the

preparatory part of the assignment set, or of learning the work covered in the demonstration period, or of answering one or two questions on the subject of the demonstration. Now and then, when the teacher finds the boys are not overworked, he may set them subjects to read from certain popular science books and ask them to write something on them.

The correcting and marking of notebooks occupy a great deal of the teacher's time. Every effort should be made to reduce this work to a minimum. Boys should be asked to copy down blackboard summaries instead of making their own notes or taking down notes when the teacher is speaking. The teacher should supervise his pupils' work when they are copying down these summaries, and it will save time if he corrects portions of written work when he goes round giving individual help during practical work. Some selected code of symbols should be used to make corrections, and the pupils themselves should be asked to correct the mistakes. The science teacher, or any other teacher, should remember that his business is to teach English as well as his special subject. Slovenly English in any form of written work should not be tolerated, and mistakes in language must be pointed out and the pupils made to correct them.

Correlation and Application

Besides imparting a training in scientific method, science teaching is important from another aspect. It is the study of science which gives us an insight into many of the natural phenomena and teaches us that scientific principles lie at the bottom of many of the simple rules of life. In order to create such an interest and foster a love for the study of science among children, it is essential that the teacher should bring home to his pupils the interesting and useful applications of its principles in daily life. Every principle of science has some useful application in

daily life. This the teacher should endeavour to emphasize in his teaching. If he does so, his lessons will become infinitely more interesting, stimulating and realistic. They will also be of direct use to his pupils. The teacher should always include in the course of teaching, whether prescribed or not, phenomena which are matters of everyday experience, and the pupils' interest in the world around them should constantly be aroused and sustained.

Science teaching can be correlated with the study of almost any subject. It can be correlated easily with mathematics. The solution of practical problems, physical measurements, graphs of temperature, rainfall and pressure, the application of geometric laws in the proofs of certain phenomena in light, laws of reflection, refraction and reflection from spherical surfaces, all pertain to the sphere of mathematics. It can be correlated with geography in that the teaching of the principles of physics and chemistry is the business of the science teacher and the teaching of the application of these principles to geography is the business of the geography teacher. All physical geography requires an elementary knowledge of science for its foundation. For example, elementary notions of scientific principles on which facts of climate depend, the construction of simple instruments used by geographers and scientists alike, practice in measuring distances by sketching and preparing plans, instruction in the use of a barometer, maximum and minimum thermometer, rain-gauge, sundial and magnetic needle, lessons on snow and ice connected with plant life and districts of heavy or low snowfall, the effects of forces that carve valleys, the action of running water and rate of flow, frost—its action on cliffs and quarry faces, wind—its action on sand, the action of waves and tides on the erosion of the coast, and the recognition of minerals such as quartz, hematite, galena, etc.

Splendid opportunities occur in the way of correlating and finding the applications of science to our bodily health.

Methods of air and water purification, disinfection, the bacterial world, digestion and the action of digestive fluids, respiration, purification of blood, temperature of the body, ventilation, sunlight and growth, the eye as a camera, the use of spectacles, sound and how the ear works, how electricity keeps our homes clean, etc.—all can be correlated with science.

Drawing and handwork too can be correlated with science. The making of models of scientific instruments, polishing articles of wood, soldering, etc., can be encouraged among boys taking up science. These things can be done during part of the handwork or science lesson, or even in the pupils' spare time in school or at home. In the drawing periods pupils can make drawings of science apparatus.

The history of the development of science is very interesting. This might be studied along with the history of certain other developments in a country or in the progress of a race. The discoveries of some important principles of science took place in the reigns of certain kings who left a mark on the history of mankind; kings and ministers often patronized science and this led to discoveries—the king of Syracuse and Archimedes, the king of Italy and Von Guericke, and so on.

Science can also be correlated with English. A science teacher, as has already been pointed out, is also an English teacher. Oral and written descriptions of observations are demanded of pupils, and these descriptions are corrected by the teacher not only from the scientific point of view but also from the point of view of language. In this way the English of the boys improves a good deal. In the composition period, the English teacher can ask them to write a description of scientific experiments which they have done in the laboratory.

Co-operation of Pupils out of School-Hours

All science teachers should take help from their pupils

when giving a demonstration. Boys can be asked to read temperatures, light spirit-lamps, hold a test-tube, pass a specimen round and do other small jobs of this kind. The science teacher should also take advantage of those boys who are more keenly interested in science by giving them work outside school-hours. They can contribute to the museum, help in making scientific models, toys, charts and diagrams, waxing tables, cleaning apparatus, and arranging articles in cupboards. They love to do these things if the teacher will only try to utilize their spirit of service. Boys will always co-operate with a teacher who likes to turn up on a holiday to do work like this. Sometimes boys who are inclined to be naughty may be entrusted with this work; the teacher will find that it is an excellent means of reforming them. Weekly monitors may be appointed to conduct the work of cleaning the apparatus.

Inspection of a Science Department

Two points should be borne in mind while inspecting:

1. The inspection should be advisory. Criticism alone should not be the motto of the inspector; the most useful criticism is constructive. If the inspector gains the confidence of the teacher and makes the latter believe he has come to help him, he can find out more about his work.

2. The individuality of the teacher's method should be respected. If his method is not altogether useless, some particular method should not be forced upon him. The teacher should be encouraged to discuss his method with the inspector who may, if he likes, suggest an alternative method, but this should not be insisted upon.

The following points should be looked for during inspection:

General arrangement — Numbers in the classes. Arrangement for theory and practical work. Hours of actual teaching and free time of the teacher. Accommodation. Timetable.

Scheme of work—If a quarterly and weekly scheme of distribution of syllabus exists, and how far it is followed.
Teacher's diary—Note daily record of work done both in theory and practical; homework set; any special feature, or difficulties noted as a result of tests or during teaching.
Textbooks—If suitable; their use, care and study.
Apparatus—If sufficient; its care and upkeep.
Co-ordination of science with other subjects—If practised.
The written work of boys—Its nature and amount; arrangements for its correction.
General progress—Both in the high and middle departments; how far the high class teacher takes interest in the middle school science work.
The stock registers—If properly maintained and if they are up to date.
Extra-curricular activities—Does a science club exist and if so, what are its activities? Were any excursions to places of scientific interest arranged during the year? Was any science fair held during the year? Were any cinema shows of films of scientific interest arranged? Details of such activities may be asked for.

Stock Registers

One of the duties of a science master is to maintain proper registers of all apparatus and chemicals in his charge. These should be neatly written, regularly checked, countersigned by the headmaster and brought up to date every year. A list of articles consumed or broken should be prepared every year, and sanction for their removal obtained from the proper authority. After these articles are written off in the registers, the latter should be brought up to date for the next year. It will facilitate the work of making the list and checking if a daily breakage and consumption (approximate) record is kept in a separate notebook. The shortage in stock at the end of the year should

tally with the total breakage or consumption (roughly in case of chemicals) recorded in this notebook.

Three registers should in all be kept in a science department :— (a) Permanent Stock Register; (b) Breakable Stock Register; (c) Consumable Stock Register. Illustrations are given at the end of this book. In (a) are entered all articles belonging either to physics or chemistry which are of a permanent nature until they become useless and are struck off—as, for example, an air pump, Leyden jar, calorimeters, electric machines, retort-stands, and tripods etc. These are entered in alphabetical order under various headings like mechanics, hydrostatics, heat, light, magnetism, static electricity, current electricity and chemistry. In (b) are entered all articles which are breakable, like flasks, funnels, beakers, spirit lamps (glass) etc. These too arc entered in alphabetical order. Two pages facing each other should be reserved for an account ranging over five years, at the end of which, the items are transferred to fresh pages to be used for another five years.

As for the Consumable Stock Register, a page is reserved for each article, these being arranged in alphabetical order. As soon as one page is full of entries, a new one is made out.

All articles purchased, even if of little value, should be entered in the Stock Register. A science teacher cannot be too careful in this respect.

Laboratory Servants

In the Punjab laboratory bearers are no longer allowed in schools. As a matter of fact they are quite unnecessary. No matter how essential they are in a college laboratory, they are not desirable in a school laboratory. The reasons are:

(i) a laboratory is a workshop where we must have workmen, and they are the boys and the teacher

(ii) it is a bad habit for small boys to be waited upon

(iii) a laboratory which cannot afford enough apparatus can ill afford a laboratory servant. The economy in expenditure thus effected can be utilized to better equip the laboratory

(iv) in a well-disciplined laboratory, all the work can be done by the boys if it is organized on the lines suggested on page 44 under the heading 'Laboratory Discipline'.

The advantages of abolishing the posts of laboratory servants in schools are that the teacher has full control of the apparatus, the responsibility for damage and breakage is fixed on the spot, and there will be no temptation on the part of the boys to get apparatus set up by someone else.

Scientific Hobbies

Now that more and more attempts are being made to give a technical bias to our education, a science master can make a valuable contribution in this direction by encouraging a number of hobbies that bear directly on education in science. Pupils will be found only too enthusiastic, and will not grudge spending time and some money if the science teacher is keen and knows the particular hobbies he is going to start. An attempt should be made to begin with one or two simple and inexpensive ones. To start too many hobbies will defeat the purpose, for the teacher will not have the time to give effectively instructions in all of them. A few useful hobbies that may be started as allied activities of the science department are ink making, soap making, oil refining and making hair-oils, making of face-cream, tooth-powder and nail-polish, making of phenyle, making of jams, vinegar, achars and chutneys, removal of stains, dry cleaning, preparing wood polish, mixing of paint and varnishing, making mosquito oil or mosquito cream, photography, blackboard paint and canvas shoe polish and making of chalk sticks.

The scope may be enlarged as the demand increases.

APPENDIX I

SCIENCE SYLLABUSES PRESCRIBED IN THE PUNJAB

1. General Science for the Primary Classes

(Prescribed in 1950)

Class I

1. Plant Life. Recognition of some plants and flowers in the neighbourhood.

2. Animal Life. Recognition of some birds and animals found in the neighbourhood. Keeping and feeding of pet animals and birds.

3. Cleanliness and health. Need and importance of personal cleanliness, use of dust-bins, buckets, latrines, urinals, etc. Keeping clothes, floor and other articles of use clean. Not to spill ink on them.

4. General:

(*a*) Sunrise and sunset. Knowledge of directions.

(*b*) Air. Its importance in life—fresh and impure air.

(*c*) Water. Pure and clean, sources of water, simple methods of cleaning water (decantation and filtration).

(*d*) Clean and dirty food.

Class II

1. Plant Life. Names of various plants, trees and crops. Learning to enjoy the beauty of flowers in colour, form and smell. Different parts of a plant. Observation of a growing plant, things necessary for its growth.

2. Animal Life. House of animals, keeping and feeding of pets. Recognition of some more birds, stories about the life of a few birds.

3. Cleanliness and health programme regarding self and surroundings as in Class I.

4. General:
   (*a*) Insects, worms and reptiles found in the neighbourhood.
   (*b*) Seasons and their effect on life.
   (*c*) Safety first. How to protect one's self against fire. How to extinguish fire.
   (*d*) What to do in case of simple injury.
   (*e*) What the sun and moon do for us.
   (*f*) Common uses of water and air.
   (*g*) Food: rotten, stale and overripe. Harm done by injudicious and over-eating, protection of food.
   (*h*) Knowledge of directions and its use.

Class III

1. Plant Life. Plants provide us with food, shelter and clothing.
2. Animal Life: (*a*) Insects. Useful and harmful to plants. Life-history of a butterfly and a grasshopper. (*b*) Birds—useful and harmful, their utility. Restrictions imposed on killing of birds.
3. Cleanliness and health programme to be the same as in Class II.
4. General:
   (*a*) Importance of air in human, animal and plant life. More information about uses of air.
   (*b*) Water—Its purification with alum; distillation.
   (*c*) Food: raw and cooked. Milk and milk products.
   (*d*) Our mode of living in respect of seasonal changes.
   (*e*) Sun, a source of heat and light. Simple demonstration of day and night with home-made globe and electric torch or a lantern.

Class IV

1. Knowledge of the various types of soil.
2. Food, what food is good for health?

3. Elementary knowledge of infectious diseases and how to check them.

4. Water cycle in nature.

5. Use of common medicines, potassium permanganate, tincture of iodine, quinine. Cleanliness programme to be continued.

6. Simple idea of the three forms of matter.

7. Stories about the lives of some prominent scientists and their inventions.

Class V

1. Study of roots, stems and flowers of different plants.

2. Village cleanliness campaigns, disposal of waste material. Their importance in individual and social life, and their scientific background.

3. Detailed knowledge about infectious and contagious diseases and how to prevent them, preparing charts, posters, and health cards. Life-history of the fly, mosquitoes and other insects which cause disease. How to control these insects.

4. Temperature and how to record it. How to take the temperature with a clinical thermometer.

5. Air, its properties and uses, how purified in nature. Ventilation, how to check draughts. Breathing and burning and their importance in life. Water vapours and dust particles in air.

6. Water, its purification. Infection carried with it and diseases caused. Its relation to industry and commerce.

7. Trees, their relation to rainfall. Importance of forests.

8. Food, various types of food, their nutritive value, digestive system and digestion of food.

9. Intoxicants and their evil effects on health.

10. Stories about some prominent scientists and their inventions.

2. Everyday Science for the Middle Classes

(Prescribed in 1950)

Class VI

Living and non-living bodies; plants—living bodies; various parts of plants and their main functions; uses of plants with special reference to soil conservation and supply of fuel to save cattle dung; importance of air and water to plants and animals; absorption of plant food by roots (red-ink experiment), transpiration in leaves.

Three states of matter and their properties; unit of measurement; measurement of length, area and volume; use of common balance.

Expansion of solids, liquids, and gases on heating and practical application; thermometers (Fahrenheit, Centigrade, clinical and maximum and minimum).

Human food, its main constituents; a balanced diet: how plants provide us with food; value of milk, vegetables and fruit in diet.

Simple chemical operations like sublimation, crystallization, and distillation; their uses in daily life; separation of simple mixtures like salt and sand.

Life-history of a fly and a mosquito; diseases carried by them; how to get rid of flies and mosquitoes.

Cleanliness of home and school and their surroundings.

Cleanliness of the room of a patient; making the room cheerful; ventilation; patient's bed; measurement of doses of medicine and timely administration of the same; taking temperature and counting of pulse.

Practical work and hobbies

1. Growing a few flowering plants, collection of leaves, roots, flowers, etc., and arranging them in albums.
2. Separation of clay and sand in a sample of soil by

decantation; filtering of muddy water, distillation and separation of mixtures like sand and salt.

3. Making crystals of nitre and copper sulphate.
4. Measurement of lengths, areas of plots, etc., weighing farm produce with a pair of scales; use of a spring balance; measurements of doses of medicine.
5. Red-ink experiment and transpiration in leaves.
6. Finding temperature of a room and water.
7. Use of a clinical thermometer, counting of pulse.
8. Study of the life-history of a mosquito or a house-fly by actually rearing these insects.
9. Preparation of spirit polish and blackboard paints.

Class VII

How plants and animals provide us with clothing; life-history of a silk-worm and a cotton plant; seed formation in plants; pollination and fertilization, importance of insects in this process; dispersal of seeds, germination of seeds, conditions necessary for germination (temperature, moisture and air).

Pressure in liquids, Bramah press, buoyancy of water, simple law of floating bodies and its application, lactometer.

Atmospheric pressure, barometer, its use; pumps—air-pump, bicycle pump, water-pump, lift-pump and siphon.

Transmission of heat in solids, liquids and gases and applications in daily life; melting point of solids, its application in daily life; freezing and boiling points of water, vaporization; water vapour in nature, clouds, rain, mist, frost, dew, rain-gauge; steam-engine; Davy's safety lamp for miners, thermos flask; expansion of water on freezing and its importance in soil formation and to water animals.

Physical and chemical changes; air a mixture; its constituents, oxygen and carbon dioxide; their preparation, properties and uses; purification of air by natural agencies;

carbon assimilation in plants; burning and breathing, respiration in plants; oxidation and rusting, their application in daily life.

Cleanliness of village streets, village well and pond; drainage in village; drinking water for men and animals, common impurities found in water, simple method of purification; town water-supply; prevention of breeding of mosquitoes in stagnant water around the house and village.

Patient's diet and how to serve, how to keep the patient cheerful by providing healthy recreation according to age.

Practical work and hobbies:

(i) Preparation of seed beds and sowing seeds; observing the process of germination in peas, wheat and gram and demonstrating three essential conditions (presence of moisture, suitable temperature and air).
(ii) Use of a lactometer.
(iii) Boring of corks, cutting and bending of glass tubes, setting up of a siphon.
(iv) Experiment to show that water is a bad conductor of heat.
(v) Preparation of oxygen and carbon dioxide and study of their properties.
(vi) Burning and breathing.
(vii) Study of the effect of light and darkness on plant growth.
(viii) Fruit preservation, preparation of achars, squashes and murabbas.

Class VIII

How plants provide us with shelter; ornamental and medicinal value of plants illustrated by examples of important plants in the locality. Principle of Archimedes; its application in daily life; density of solids and liquids,

Lever, kinds and their use in daily life with particular reference to implements used in agriculture, spinning and

weaving; pulleys, inclined plane and screw and their use in agriculture, spinning and weaving.

Cooling by evaporation, wet and dry bulb thermometer and its use in weather forecasting.

Light travels in straight lines; pin-hole camera, shadows and eclipses; magnifying glass.

Magnet, its properties, use of magnetic needle; making magnets.

Simple cell, Leclanché cell and dry cell; use of electricity for heating and lighting and in agriculture; an electric torch and bell; lightning and thunder, how to save buildings from lightning; how to use ordinary electrical appliances like electric lights, fans, heaters and irons. Precautions in the use of electric current.

Elements and compounds, distinction between a mixture and a compound, names of some important elements; metals, and non-metals; elements essential to plant-growth; natural and chemical manures.

Acids, alkalis and salts; observation of the action on brass, iron, zinc and copper of common acids including vinegar, lemon juice and tamarind; action of alkalis on oils, soap-making.

Water, its value in nature as a solvent; hard and soft waters; washing of clothes and removal of stains like oil, turmeric, etc.

Bacteria in relation to human health and agriculture; fermentation (vinegar); nitrogen; its importance in air, and use for plant life, nitrifying bacteria, disinfection, names and use of a few common disinfectants; infectious diseases like plague, cholera, smallpox and tuberculosis.

Refuse and its disposal; manure pits and composts.

Making of poultices, i.e., linseed and mustard; application of fomentation, wet and dry.

The human body as a fortress:

(*a*) Outer-wall, the skin.

(*b*) Watchman on the wall, the skin, sense organs, sight, sound, smell, taste and touch.

(*c*) The fort:

(i) Air, respiratory system.
(ii) Portal—circulatory system.
(iii) Food—its distribution—alimentary system.
(iv) Sewage—excretory system: (*a*) skin, (*b*) kidney, (*c*) breath, (*d*) bowels.
(v) Defence—bacteria.
(vi) Officials of intelligence—nervous system.

Practical work and hobbies

1. Determination of the boiling point of water. Principle of Archimedes; to find density of solids.
2. Light travels in straight lines.
3. Making magnets, use of magnetic needle; setting up a simple cell, a Leclanché cell and an electric bell. Putting fuses and making connexions in holders, plugs, etc. Precautions in connexion with the use of electric appliances.
4. Distinction between acids and alkalis.
5. Action of vinegar and lime-juice etc., on common metals of daily use.
6. Test if a sample of water is hard or soft; the softening of hard water.
7. Removal of common stains.
8. Preparation of soaps and hair-oils.
9. Growing of some kind of plant in flower pots, using artificial manure, compost, natural manure and no manure.

Revised Syllabus for General Science for Classes I To VIII (Prescribed In 1962)

Aims—

(1) To give pupils an intelligent and appreciative outlook on nature.

(2) To encourage pupils to observe things around them and test their observations by experiments, thus stimulating in them the spirit of scientific inquiry.
(3) To enable them to understand the scientific principles exemplified in the natural phenomena around the application of science, for the service of man.
(4) To introduce them to the important incidents in the lives of some great scientists.

Note—The syllabus in General Science will have to be taken up in correlation with Health Activities and the Basic Craft in the Junior Basic School. In Primary Schools this subject is to be taught in correlation with children's activity under the activity programme.

Class I (Oral Work)

1. *Plant Life*—Recognition of some plants and flowers in the neighbourhood.
2. *Animal Life*—Recognition of some birds and animals found in the neighbourhood.
3. *Cleanliness and health*—Need and importance of personal cleanliness.
4. *General*—
   (a) *Sunrise and sunset*—Knowledge of directions.
   (b) *Air*—Its importance in life.
   (c) *Water*—Pure and clean water.
   (d) *Food*—Clean and dirty food.
5. *Outdoor activities*—Visiting the school garden and the fields in the neighbourhood.

Class II

1. *Plant Life*—Names of some common plants, trees and crops; different parts of a plant.

2. *Animal Life*—House of animals, keeping, feeding, and care of pets.

Recognition of some more birds.

3. *Cleanliness and health programme*—The same as in Class I.
4. *General*—
   - (a) Insects, worms and reptiles found in the neighbourhood.
   - (b) Seasons and their effect on life.
   - *(P) (c) Safety first. How to protect one's self against fire. How to extinguish fire.
   - *(P) (d) What to do in case of simple injury.
   - (e) Common sources and uses of water; common uses of air.
   - (f) *Food*—Rotten, stale and over-ripe. Harm done by injudicious and over-eating. Protection of food.
   - *(P) (g) Knowledge of direction and its use.
5. *Outdoor activities*—The same as in Class I.

Class III

1. *Plant Life*—Uses of plant—food, shelter and clothing.
2. *Animal Life*—
   - (a) *Insects*—Useful and harmful to plants. Life-history of a butterfly and a grasshopper.
   - (b) *Birds*—Useful and harmful, their utilities, restrictions imposed on killing of birds.
3. *Cleanliness and health programme*—Use of clean clothes, floor, dust-bins, latrines and urinals, etc.
4. *General*—
   - (a) Importance of air for human, animal and plant life.
   - *(P) (b) *Water*—Its purification by decantation and filtration.
   - (c) *Food*—Raw and cooked; milk and milk products.
   - (d) Our mode of living in respect of seasonal changes.

* (P) indicates practical work.

(e) *Sun*—A source of heat and light; simple demonstration of day and night with home-made globe and electric torch or a lantern.

5. *Outdoor activities*—Collection of butterflies and grasshoppers.

Class IV

*(P) 1. *Plant Life*—Germination of seeds; conditions necessary for germination; importance of air, water, and sun for plants.
2. *Animal Life*—General classification of animal kingdom, i.e., insects, reptiles, birds, mammals and aquatic animals, specifically fish and frog.
3. *Impurities in air*—Purification of air by natural agents, i.e., sun, rain, storm and plants.
4. *Water cycle in nature*—Purification of water by distillation.
5. Cleanliness of home and its surroundings.
6. *Food*—What food is good for health?
7. Elementary knowledge of infectious diseases and how to check them.
8. Stories about the lives of some prominent scientists like Pasteur and Wright Brothers.
9. *Practical work and outdoor activities*—Collection of insects, reptiles and aquatic animals for the school museum.

Class V

1. *Plant Life*—Functions of different parts of a plant.
2. *Animal Life*—Life-history of a house-fly and a mosquito.
3. *Air*—Its properties and uses, ventilation.
*(P) Breathing and burning and their importance in life.
4. *Water.*—Its relation to industry and commerce.
*(P) 5. Cleanliness of school and its surroundings.
6. *Food*—Simple account of various important types of food and their functions; a balanced diet.

* (P) indicates practical work.

7. A simple idea of the solar system.
8. *Fire*—The discovery of fire by man. Used for heating, cooking, drying clothes, softening metals, melting, burning refuse and infected clothes. Fire kills germs.
9. Stories about some prominent scientists like Galileo and Edison and their inventions.
10. *Outdoor activities*—Growing of some common flowering plants in the school garden.

Class VI

1. *Plant Life*—Uses of plants—
   (a) Medicinal uses.
   (b) Ornamental.
   (c) Conservation of soil and importance of forests.
   (d) Industrial uses.
2. *Unit of measurement*—Measurement of length, area and volume; uses of common balance; three states of matter and their properties.
3. *Expansion of solids, liquids and gases on heating and its practical application.*
   Thermometers—Centigrade, Fahrenheit, clinical, maximum and minimum.
4. *Sun*—Its size compared with the earth. Its distance from us. Time for light to travel from the sun to us. Speed of light, shadow, eclipses, light travels in straight lines.
5. Journey of food, and digestion.
6. Simple chemical operations like sublimation and crystallization, their uses in daily life; separation of simple mixtures like sand and salt.
7. Cleanliness of the room of a patient; making the room cheerful, ventilation, patient's bed.
8. Important organs of the body and their functions.
9. Life stories of some eminent scientists like P. C. Ray and J. C. Bose.
10. *Practical work and hobbies*—(i) Collection of leaves, roots and flowers and arrangement in albums. (ii) Separation of

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clay and sand in a sample of soil by decantation; filtration of muddy water, distillation. Separation of mixture like sand and salt. (iii) Making crystals of nitre and copper sulphate. (iv) Measurement of lengths, areas of plots, etc. Weighing of farm produce with a pair of scales; use of a spring balance; measurement of doses of medicines. (v) Finding temperature of a room and water. (vi) Use of a clinical thermometer, counting of pulse. (vii) Preparation of spirit polish and blackboard paint.

Class VII

1. *Plant Life* — Pollination, fertilization (seed and fruit formation), dispersal of seeds and fruits.
2. *Cleanliness* of village streets, wells and pond. Drainage in village, drinking-water for men and animals, town water-supply.
3. Pressure in liquids, Bramah press, buoyancy of water. (Principle of Archimedes). Simple law of floating bodies and its applications, and lactometer.
4. Atmospheric pressure, barometer, its use, pumps, air-pump, bicycle pump, water-pump, lift-pump and siphon.
5. Transmission of heat in solids, liquids and gases, their applications in daily life.
6. Mirrors and lenses, simple idea of reflection and mention of the use of convex lens without description.
7. Physical and chemical changes, oxygen and carbon dioxide, their preparation, properties and uses; respiration in plants; oxidation and rusting, their application in daily life.
8. Respiratory system.
9. Life stories of some eminent scientists like Davy and Priestley.
10. Practical work and hobbies—
    (i) Use of lactometer.
    (ii) Boring of corks, cutting and bending of glass tubes, setting up of a siphon.

(iii) Experiment to show that water is a bad conductor of heat.

(iv) Preparation of oxygen and carbon dioxide and study of their properties.

(v) Study of the effect of light and darkness on plant growth.

Class VIII

1. Different types of soils, importance of manures to plants.
2. Levers, their kinds and uses in daily life with particular reference to implements used in agriculture, spinning and weaving; pulleys, inclined plane and screw and their uses in agriculture, spinning and weaving.
3. Moisture in the air; clouds and mist, dew, rain, hail, snow, the refreshing and cooling effect of wind and breeze, wet and dry bulb thermometer, why clothes do not dry in the rainy season.
4. Dispersion of light by prism — white light composed of seven colours, colours of the rainbow.
5. Magnets, their properties, use of magnetic needle, making magnets, electromagnets, mention of their uses.
6. Simple cell, Lechlanché cell and dry cell, simple uses of electricity, electric torch and bell. Precautions in the use of electric current.
7. Elements and compounds, distinction between a mixture and compound. Names of some important elements, metals and non-metals.
8. Acids, alkalis, and salts; soap making.
9. *Water* — Hard and soft waters, washing and cleaning.
10. Bacteria in relation to human health; diseases caused, (i) by air (e.g., tuberculosis and small-pox), (ii) by water (e.g., typhoid and cholera), (iii) by contact (e.g., scabies and sore eyes), and (iv) by insect bite (e.g., plague and malaria).
11. Refuse and its disposal.
12. Circulatory system.

13. Life stories of scientists like Faraday, Volta and Raman.
14. Practical work and hobbies—
    (i) Making magnets and dry cell.
    (ii) Verification of laws of reflection.
    (iii) Distinction between acids and alkalis.
    (iv) Preparation of soaps and hair-oils.
    (v) To test, if a sample of water is hard or soft and to soften hard water.
    (vi) Dispersion of light through a prism.

APPENDIX

PRACTICAL WORK IN GENERAL SCIENCE AND WORKSHOP PROJECTS FOR CLASSES VI — VIII

(*for Schools which have arrangements for manual training*)

Class VI

1. Making things with a mecanno set.
2. Making mechanical toys out of bamboo, string, wire, cardboard, elastic rubber bands.
3. Shadowgraph entertainments.
4. Making a pin-hole camera with screen.
5. Making and graduating a red-ink thermometer.

Class VII

1. Making hot-food-cans with two tins packed in cotton wool or saw-dust. Also ice-boxes.
2. Making a focal-point sunlight igniter with a convex lens fitted in a frame or box.
3. Repairing bicycles; ball bearings, and lubrication.
4. Arrangements for concealed lights for rooms and stage and under-water lighting.
5. Making a spinning wheel or a water wheel.

6. Making hot air balloons.
7. Bursting balloons by placing in the sun.
8. Arrangement of shop window with suitable lighting and mirrors to give reflected effects of articles displayed.

Class VIII

1. Seesaw (movements and leverage).
2. Making electromagnets.
3. Deflection of magnetic needle by current in a loop of wire.
4. Fixing a model home (cardboard) with electric lights (torch bulbs) and switch buttons from a Lechlanché cell.
5. Visits to mechanical workshops, railway sheds, saw-mill, lathe shop, motor mechanics or servicing stations.
6. Making and operating railway signals with remote string control passing round pulleys.
7. Using the mechanism of spring-powered toy car or toy engine for making models for lifting weights, using reels (as pulleys and string). Also other adaptations.
8. Models of electric traffic control signs with red and green lights operated by press buttons.
9. Setting up a clock face so that an electric bell rings at a fixed time.
10. Fitting electric bells in the classrooms, burglar alarm.

For The High Classes

(*a*) Physics

Greater emphasis should be laid on experimental portions and on application of fundamental principles in everyday life.

Space, time and matter; methods of observation; recording experiment; measurement; simple measurements of length, area, volume, mass and density in British and metric systems; use of the spring balance and the simple

form of the school balance; three states of matter and their characteristic properties; Bramah press; pressure of fluids; principle of Archimedes; specific gravity of solids and liquids and their determination by hydrostatic balance; floating bodies; hydrometer; balloon; atmospheric pressure; simple barometer; water-pump and siphon.

Simple ideas of velocity, acceleration, graphic representation; elementary notions of inertia, momentum, force; three laws of motion; mass and weight; laws of gravitation; centre of gravity; equilibrium of two forces; three states of equilibrium of a body.

Moment of a force; principle of lever; simple pulley.

Source and effects of heat; heat and temperature; mercurial thermometer; maximum and minimum thermometer.

Units of heat; specific heat, thermal capacity, latent heat of water, latent heat of steam; measurement of specific heat of a solid and latent heat of water by the method of mixture.

Change of state; fusion; determination of melting point; freezing mixture; evaporation and boiling; determination of boiling point; experiments to illustrate change of boiling point with pressure; moisture in air; condensation of water vapour; dew point; cloud, rain, snow.

Conduction of heat; good and bad conductors; convection; ventilation, convection currents in nature; radiation of heat; good radiators, good absorbers and good reflectors of heat rays; condition for the formation of dew.

Sources of light; light travels in straight lines; pin-hole images, shadows, eclipses.

Reflection of light; laws of reflection of light; image of object by reflection from a plain mirror.

Refraction of light; laws of refraction of light; experimental determination of index of refraction of glass and water by the simple application of the law; refraction through a prism; dispersion by a prism; colour of bodies.

Convex lens; real images by a convex lens; experimental determination of focal length of a convex lens; convex lens used as magnifying glass; principles of photographic camera, magic lantern, astronomical telescope and micro-scope.

Electrification of bodies; positive and negative electricity; gold-leaf electroscope; conductors and insulators; charging an electroscope by friction and conduction; electric induction; charging an electroscope by induction; electrophorus.

Simple voltaic cell; local action and polarization; description of Bunsen cell, Daniell cell, Leclanché cell, two or more cells in series; production of heat and light by electric current; Oersted's experiment; principle of galvanoscope; electromagnet; electric bell; electrolysis and electroplating.

Properties of a magnet; making of a magnet; mariner's compass.

Practical Physics

The use of the yard, foot and inch, the metre, centimetre and millimetre in the measurement of simple lengths, areas and volumes.

The use of the spring balance and the simple balance; to find the relative density of a liquid by means of a specific gravity bottle; to find the relative density of a solid by Archimedes' principle; to show the action of a siphon; to show that liquids and gases expand when heated; to determine the melting point of wax and naphthalene; to determine the boiling point of water; to show the effect of reduced pressure on the boiling point of water; to compare the rate of cooling of dull and brightly polished surfaces; to show that light travels in straight lines; to prove that the angles of incidence and reflection are equal; to verify the laws of refraction; to trace the path of rays through a prism; to find the focal length of a convex lens;

to charge a gold-leaf electroscope and electrophorus; to set up a simple voltaic cell, a Daniell cell and a Leclanché cell; to determine the direction of an electric current by a magnetic needle; to set up an electric bell in a circuit; to magnetize steel, using a bar magnet; to make a simple electromagnet.

(*b*) Chemistry

Physical and chemical changes; elements, compounds, and mixtures, metals and non-metals; chemical combination and decomposition.

Solution, decantation, filtration, evaporation, distillation; saturated solution; crystals, crystallization; sublimation; composition of air; oxygen, nitrogen; impurities of air; deliquescent bodies; air a mixture.

Chemical affinity; preparation of oxygen, its properties and uses; oxidation, reduction, combustion; parts of a candle flame.

Hydrogen: its preparation and properties.

Water: its properties and composition by electrolysis; rain, spring, mineral, and sea waters; hard and soft waters; softening of hard water.

Organic and inorganic compounds: allotropic forms of carbon; coal; breathing; burning of a candle; action of plants on carbon dioxide.

Carbon dioxide: its preparation, properties and uses; limestone; lime and slaked lime; forms of calcium carbonate and calcium sulphate.

Hydrochloric acid gas: its preparation and properties; chlorides.

Sulphur: its varieties; effects of heat upon it in a closed vessel, and in air; sulphur dioxide and its properties; sulphuric acid, its properties and action on metals; sulphates; phosphorus—red and yellow; matches.

Nitric acid: its preparation, properties and uses;

nitrates; distinction between hydrochloric, sulphuric and nitric acids; ammonia and its properties.

Ores and metals, alloys and amalgams; the more important salts of sodium and potassium.

Properties of the following metals: copper, mercury, silver, zinc, lead, tin, iron and aluminium.

Practical Chemistry

Acquaintance with simple chemical manipulation, as solution, filtration, decantation, crystallization, distillation.

To fit up an apparatus to demonstrate the combination of oxygen of the atmosphere with iron.

Cork boring; cutting, bending and drawing out of glass tubing and glass rod.

The preparation and properties of oxygen and hydrogen.

The distinction between acids and alkalis; to neutralize an acid with an alkali and vice versa.

A study of the zones in a candle flame. The products of combustion as illustrated by the burning of a candle.

To distinguish between hard and soft waters and to soften hard water.

The action of heat on coal to show the production of coal gas.

The preparation and properties of carbon dioxide, hydrochloric acid and nitric acid. Tests for hydrochloric acid, sulphuric acid and nitric acid.

The action of heat on sulphur. To prepare monoclinic and plastic forms of sulphur.

For Basic Schools

General Science for Classes I, II, and III

1. The objective of the syllabus for general science is:
   (*a*) To stimulate in the children the spirit of inquiry.
   (*b*) To form in the pupils a habit of accurate observation.
   (*c*) To give the pupils an intelligent understanding of nature.

2. These objectives cannot be fulfilled by classroom teaching. The teaching of general science, therefore, should not be restricted to a period but should be correlated to other activities and to life in general.

3. All activities in connexion with the programme of gardening, cleanliness, health and craftwork should be subjects of general science.

4. The children should be taken frequently on excursions to study nature and the life of man around them. A few instances are suggested here for the guidance of the teacher:

(*a*) Crops and plants, and the part played by insects.
(*b*) The different parts of a plant.
(*c*) The different stages of growth in a plant.
(*d*) The different seasons and their effect on plants and crops.
(*e*) Sunrise and sunset.
(*f*) The dark and bright parts of the month.
(*g*) Eclipses (if any).
(*h*) Animals in the village.
(*i*) Crafts and industries in the village.

Class IV

1. The life of a plant—the different parts of plants and their functions.

2. The beginning of the study of the human body.

3. Insect life—the life-history of the mosquito—malaria and malarial fevers (wherever prevalent) and mosquito preventive measures.

4. Spiders, scorpions and snakes—spiders and snakes as helpers of man.

5. Recognizing principal constellations and planets.

6. Day and night—the seasons.

Class V

1. In connexion with cleanliness:

(*a*) Different forms of disposal of night-soil. Trench

latrines and their advantages. How deep should the trenches be and why. How night-soil is converted into manure.

(b) Bacteria and their work.

(c) How to make soak pits and for what purpose.

(d) Flies, mosquitoes and lice, their life-history, how to prevent them.

2. Health and hygiene:

(a) Air: the value and need of fresh air.
Physical properties of fresh air.
Impurities in the air and its purification.
Air in a crowded room.
Need for ventilation.
Method of ventilation.
Draughts.
Process of breathing.

(b) Water: pure water, impurities in water.
Its importance to plant, animal and human life.
Composition of water.
Common infection carried by water.
Diseases caused by impure water.
The village well, tank or river.
Methods of purifying and disinfecting impure water.

(c) Food: different kinds of food and their nutritive value.
The digestion of food.
The digestive system.
How, when and what to eat.

3. The heavenly bodies:

(a) The solar system—the mutual relationship of the sun, moon and the planets. How are eclipses caused?

(b) Phases of the moon—the bright-half and dark-half of the month.

(c) Acquaintance with the main stars and constellations. The Milky Way.

SYLLABUS FOR GENERAL SCIENCE FOR HIGHER SECONDARY CLASSES
(in use in 1961)

Course Content	*Demonstrations*	*Experiments*	*Outdoor Activities*
UNIT I: *Our Surroundings.*			
(*a*) The earth, rocks and soil; different kinds of rocks and minerals.	Three classes of rocks. Identification of minerals. Identification of fossils.	Study of some common rocks, ores and minerals. Study of broken rock with a magnifier. Test for limestone. Mounting rock and mineral samples. Making a model of a volcano.	Visit to a rock exposure, river, tunnel, rock quarry or a mine. Collection of minerals and ores.
Formation of soil and its chief constituents; different kinds of soil, maintaining the fertility of the soil; soil erosion and conservation.	Different types of soil. Chief constituents of soil. Soil contains air. Properties of soil particles of different sizes. Difference in fertility. Acid, alkaline and neutral soils. Prevention of soil erosion.	Effect of different kinds of soils on growing things. Ascent of water in fine tubes. Rise of water in different types of soil. Increasing soil productivity. Preparing and using of compost (Group Project).	Field trip to study erosion of soil. Collection of samples of different types of soils. Observation of earth worms in the soil.
(*b*) Plants—different kinds of plants; cultivated plants: cereals, legumes, vegetables, fruits and ornamental plants; timber trees; medicinal plants.	Explanation of charts and slides of different species of plants, cereals, legumes, vegetables, fruits, flowers.	Identification and broad classification of common plants.	Visit to a field, an agricultural farm, a botanical or public garden for observing and collecting plant specimens.
Cultivation of food-grains. Seasonal crops and crop rotation. Implements used.			Preparation of a school garden.

(c) Animals—General classification: domestic and wild animals; animals as sources of food; wool; skins and hides; draught animals and pets. Insects, useful and harmful. Birds, useful and harmful. Protection of wild life.	Explanation of charts, slides and films showing different species of animals, reptiles, birds and insects.	Listing of domestic and wild animals, serpents, birds and insects in the neighbourhood of the school. Construction of a pond in the garden for observing fishes, tadpoles, frogs, water insects, and water plants. Poultry-keeping (Group Project).	Visit to a zoological garden and a museum. Excursions to forests, rivers, mountains, and sea for observation and collection of specimens of different kinds of animals. Visit to a fish hatchery.
(d) The universe around us —sun, planets, moon and stars; seasons and calendar; tides.	Explanation of charts, slides, and films showing stars, constellations, nebulae, milky-way, solar system, comets, meteors, phases of the moon, tides, eclipses. Use of a telescope for observing planets. *Models*: Rotation and revolution of the earth and moon-eclipse.	Recording the position of the sun and variations of the day in different seasons. Recording the different phases of the moon. Observation of the movement of planets. Construction and use of a simple sextant and sun-dial. Setting up of a model of the solar system (Group Project).	Visit to an observatory. Outings at night for observing and locating some of the major constellations, planets and shooting stars.
UNIT II:—*Nature of Things.*			
(a) *Air*—The atmosphere around us; the pressure of air.	Demonstration of air pressure: crushing can experiment; Magdeburg's hemispheres; Bursting of a balloon. Construction and use of simple barometer; Aneroid barometer.	Making a toy model of windmill; suction of water through straw and eye-dropper. Construction and use of a siphon.	Study of weather charts from newspapers. Visit to a meteorological observatory.

Course Content	Demonstrations	Experiments	Outdoor Activities
Syringe, siphon, pumps.	Construction of a syringe. Football inflator; cycle pump; common pump (lift pump); air pump; force pump; fire engine.	Using a rubber tube as a siphon. Models of a flush tank and water basin (Group Project). Recording of variations in the atmospheric pressure.	Observation of lizards walking on walls and rubber toys that stick by pressure.
Moisture in the air (rain, dew, mist, fog, snow and hail).	Condensation of moisture in the air—wet and dry bulb thermometers.	Readings of dry and wet bulb thermometers in dry and wet seasons.	Construction of rain-gauge and recording rain-fall (Group Project).
Composition of air; oxygen and carbon dioxide; Burning and breathing: rusting, and its prevention (paints); pollution of air and its prevention. Natural cycle of purification of air.	Bell-jar experiment with yellow phosphorus, candle and iron filings; lime water test. Preparation and properties of oxygen. Preparation and properties of carbon dioxide.	Making a fire extinguisher (Group Project).	Observation of chimneys and smokeless *chulha*.
(b) *Water:* Sources of water, storage and distribution. Hard and soft water.	Purification of water: filtration, distillation, chlorination. Use of chlorogen and	Sedimentation and decantation of muddy water. Use of soap with different kinds of	Visit to water-works. Distribution of water by pumping and gravitation.

	potassium permanganate. Demonstration of hard and soft water; removal of hardness of water.	water (before and after boiling).	
Physical properties of liquids. Relative density, Archimedes' Principle. Floatation and Hydrometer (functional treatment only).	Pressure of liquids in different directions. Simple hydraulic press. Relative density of a liquid not mixing with water—Hare's apparatus, U-Tube. Archimedes' principle, socket and cylinder experiment. Lectometer in pure milk, skimmed milk, diluted skimmed milk.	Determination of safety lines in toy-boats in different liquids.	Observation of swimming aids, life-belt, inflated rubber-tube, pitcher. Transport of logs by water. Observation of meteorological balloons and toy balloons.
Composition of water: Hydrogen and oxygen.	Electrolysis of water and testing of the gases released. Preparation and properties of hydrogen; oxyhydrogen flame.	Verification of properties of oxygen and hydrogen.	Observation of gas welding.
(c) Physical and chemical changes. Mixtures and compounds.	Experiments to show physical and chemical changes. Simple demonstration of mixtures and compounds—sulphur and iron.		
Separation of mixtures.	Separation of components of mixtures by (a) filtration, (b) distillation-sugar solution. coloured water (c) evaporation and crystallisation — saline	Separation of constituents of a mixture such as sand and sugar.	Visit to a sugar factory.

Course Content	*Demonstrations*	*Experiments*	*Outdoor Activities*
	solution or copper sulphate solution (*d*) sublimation-iodine or ammonium chloride.		
Acids and alkalis—their operties, neutralization and rmation of salts. Sources of mmon salt.	Identification of an acid, alkali and neutral solution with litmus. Neutralization of an acid and an alkali.	Testing properties of acids and bases of common use—lemon, vinegar, lime caustic soda, baking powder, fruit salt. Action of acids like lemon, curds etc. on common household utensils.	
Common metals—iron, pper, aluminium, zinc, ld, silver, lead, tin and eir important uses. Common alloys—brass, bronze, l-metal, german silver, der, type-metal, stainless el.	Demonstration of common ores and metals.		
Non-metals—carbon and l; different kinds of bon; products of distilon of coal and their uses.	Absorbing ammonia gas with a piece of carbon. Filtering jaggery solution through animal charcoal.	Observation of non-metals of daily use and listing their uses. Exhibition of products of coal in daily use and preparation of a chart to show the same.	
Sulphur—properties and s.	Burning sulphur in air, test for sulphur dioxide: litmus, potassium permanganate; bleaching action of sulphur dioxide.		Visit to a vulcanizing workshop.

Sulphuric acid: important properties and uses.	Action of sulphuric acid on metals and on water.		
Phosphorus — red and yellow; important properties and uses.	Physical properties of red and yellow phosphorus; burning phosphorus in air.		Making and firing of crackers.
Chlorine—disinfecting and bleaching properties and uses. (c) Common things we use—paper, matches, soap, glass, ink.	Bleaching action. Preparation of bleaching powder. Films and filmstrips.	Experiments by way of projects. 1. Preparation of matches. 2. Preparation of soap. 3. Preparation of inks. 4. Preparation of paper.	Visit to match, glass, paper and soap factories.
Use of sodium carbonate, sodium bicarbonate (washing soda and baking soda), Epsom salt, alum, potassium nitrate, copper sulphate, limestone (marble, chalk); fertilizers—natural and artifical; insecticides and disinfectants; Phenyle, D.D.T., dettol, lysol, bleaching powder, potassium permanganate, iodine, sulphur dioxide, lime, hydrogen peroxide.			
UNIT III: *Energy and Work*			
(a) Heat—Sources of heat: sun, fuels, electricity and friction; sun is the prime source of all energy on earth.	Chart showing transformation of energy. Ball and ring experiment. Bar breaking. Expansion of different metals.	Burning paper by using solar energy.	Visit to a railway track and an iron bridge.

Course Content	*Demonstrations*	*Experiments*	*Outdoor Activities*
Heat and temperature. Effects of heat; expansion of solids, liquids and gases and their applications.	Experiments showing expansion of liquids and gases.		
Thermometers — simple ideas of different scales; maximum and minimum thermometer, clinical thermometer.	Construction and calibration of a thermometer.	1. Relation between Centigrade and Fahrenheit scales. 2. Reading a thermometer (including clinical).	Recording maximum-minimum temperatures as part of weather study. Preparation of a clinical temperature chart of a patient. Visit to some cold storage plant.
Heat transmission—conduction, convection, radiation; their common applications. Domestic heating, air conditioning. Thermos flask.	(*a*) Convection of liquids and gases. (*b*) Conduction, Ingenhauzs' apparatus. (*c*) Radiation—demonstration with ether thermoscope. (*d*) Effect of pressure on vapour.		
Melting point, boiling point, specific heat, and qualitative study of latent heat; boiling, evaporation condensation; simple applications in daily life.	1. Melting point and boiling point of different substances. 2. Preparation of ice by cooling action of evaporating ether.		Visit to an ice factory.
(*b*) Light: luminous and non-luminous bodies; rectilinear propagation and speed of light; reflection—plane and curved	Experiments to demonstrate plane reflection, formation of images, reflection at concave and convex surfaces,	1. Construction of a pinhole camera. 2. Construction of periscope,	

mirrors; periscope, kaleidoscope and their uses.		3. Construction of a kaleidoscope.	
Refraction through glass and water. Lenses and their use.	1. Relevant experiments. 2. Formation of images due to refraction through lenses.	1. Observation of refraction and total internal reflection. 2. Identification of convex and concave lenses.	Observation of twinkling of stars. Observation of apparent depth.
Camera, eye, microscope and telescope; magic lantern, motion picture.	Demonstration of parts and functions of camera and model of the eye; telescope, microscope, magic lantern and film projector.		
Prism: colour and rainbow.	Using a prism to demonstrate formation of a spectrum.		Observation of rainbow, and halo round the moon.
(c) Sound: production by a vibrating body; material medium necessary.	1. Pith balls and glass cup. 2. Sonometer. 3. Vibrating tuning fork. 4. Bell jar and electric bell.		
Simple musical instruments—stringed, wind, reed and percussion instruments; reflection of sound, echo; how we hear (ear).	1. Demonstration of the model of the ear. 2. Working of sound box of a gramophone.	Preparation of Ektara (single stringed) or Tambura.	Making a string telephone, flute, etc. Hearing of echoes.
Toy telephone and phonograph.			Visit to a musical instrument shop.

Course Content	Demonstrations	Experiments	Outdoor Activities
(d) Magnetism: natural and artificial; properties of magnets; earth as a magnet, magnetic needle and its use for navigation on sea and in air; mariner's compass.	Mapping the magnetic field of a magnet with iron filings.	1. Magnetizing steel strips. 2. Preparation of mariner's compass. 3. Construction of a magnetic toy.	
(c) Electricity production: frictional electricity (positive and negative); primary cells—Voltaic cell, Leclanché cell (wet and dry), storage cells, motor battery (simple treatment of the above).	Demonstration of the parts and working of the cell.	Preparation of a dry cell.	
Alternating and Direct currents. Dynamo (very simple treatment). Distribution of electricity. Insulators and conductors.	Demonstration of working models.	Making a small electric dynamo and motor (Group Project).	
Effects of electric current: heating, lighting, magnetic and chemical.	Thermal effects and magnetic effects—electric motor, working model of a telegraph.		
Domestic uses of electricity: electric heater, electric iron, electric lights, electric	Working of a simple radio set (single valve) and crystal set.	1. Construction of an electromagnet. 2. Recording of an electric meter, and calculation of units of energy.	Study of a household electric circuit for lighting.

bell, electric fan, telegraph, telephone, loudspeaker, microphone and radio.		3. Replacing a fuse, a switch and plug. Handling of an electric iron, stove and heater. Study of the fan regulator. 4. Electroplating. 5. Assembling of an electric bell.	Visit to an electric power house and telephone exchange.
(*f*) Atomic energy: constitution of an atom and production of atomic energy.	Relevant films and filmstrips.		
(*g*) Simple machines: levers, weighing machines, gears, wheel and axle, pulleys.	Demonstration experiments.		Visit to a machine shop and factory.
Wind and water mills: engines—steam and internal combustion.	Demonstration of a working model, films and filmstrips.	Preparation of charts and models showing application of levers, pulleys, etc.	Visit to oil mills, motor workshop and loco-shed. Observation of mechanical toys and Amber Charkha.
UNIT IV: *Life*			
Living and non-living objects.	Filmstrips to show the characteristics that distinguish the living from the non-living.		
The basis of life: cell, protoplasm and tissues.	Examination of onion peel under the microscope to study various parts of the cell.		

Course Content	*Demonstrations*	*Experiments*	*Outdoor Activities*
	Examination of staminal hairs of Tradescantia under the microscope to see the streaming nature of protoplasm. Slides of different kinds of tissues to be shown through the micro-projector.		
Plants and animals: simple forms of life—bacteria, protozoa and moulds.	Examination of a drop of water by means of a micro-projector.	Examination of bread and other moulds. Examination of a drop of water under microscope.	
Parts of a flowering plant.	Sketches of the parts of some common plants.		
Nutrition in plants and animals. Carbon and nitrogen cycles.	1. Photosynthesis: evolution of oxygen by plants in sunlight. 2. Formation of starch in a green leaf. 3. Action of saliva on starch.	Experiment to demonstrate the absorption of water from the soil by plant. Preparation of charts of carbon and nitrogen cycles.	
Growth and reproduction in plants. Simple ideas of reproduction in animals including man.	1. Pollination by artificial transference of pollen. 2. Slides on fertilization by means of micro-projector. 3. Vegetative propagation: cutting, grafting and budding. 4. Experiment on conditions of germination.	1. Recording the growth and change in plants and animals as observed from the school garden and pond. 2. Sowing seeds of bean, gram and maize. Study of the changes during germination.	Visit to an experimental farm, a horticultural garden, and a nursery.

	5. Experiment on conditions of growth. 6. Charts, films and filmstrips showing reproduction in plants and animals.		
Irritability and movement.	Experiments on hydrotropism, geotropism and heliotropism. Experiments on sensitive plants like *Mimosa Pudica*.	Simple experiments to show curving of roots towards gravity and moisture.	Observation and recording of plants that have leaves and flowers that close at night. Observation of movement of creepers and tendrils towards sunlight and round the support.
Changing pattern of life—organic evolution.	Charts and films of fossils.		
UNIT V: *Human Machine—its needs and care.*			
Human skeleton, viscera of a goat, sheep or rabbit. Charts and models of human viscera. (*a*) General structure of the human body.		Sketching of human viscera from the model showing the relative position of the organs.	
Digestion.	Action of enzymes on food in aiding digestion: pepsin, renin, bile and pancreatic juices. Films on digestion in man.	Experiment to show the action of cold and hot saliva on starch and in acid and alkaline medium.	

Course Content	Demonstrations	Experiments	Outdoor Activities
Circulation.	1. Demonstration of the capillary circulation in webbed foot of frog under a microscope. 2. Examination of blood corpuscles by means of a micro-projector. 3. Films on blood circulation. 4. Pressure of blood, using manometer.	1. Examination of the heart of a goat or sheep. 2. Feeling and counting of pulse of persons of different ages and making a record of the same.	Use of tourniquet.
Respiration.	1. Experiments to demonstrate the working of lungs by means of blowing through a glass-tube and by bell-jar experiment. 2. Charts on deep breathing and artificial respiration.	1. Examination of the lungs of a goat. 2. Handling a stethoscope. 3. Experiments to show the difference between the carbon dioxide content of inspired and expired air by their comparative effect on lime-water.	Artificial respiration.
Organs of excretion: (*a*) skin (*b*) kidneys.	(*a*) Skin—chart and model of vertical section of skin. (*b*) Kidneys of a goat. (*c*) Chart showing the structure of kidneys.	Examination of source of skin (pores and hair) under a lens.	
Nervous system: Brain and spinal cord.	1. Demonstration of sheep's brain. 2. Model of human brain. 3. Reflex action; knee jerks; experiment on decapitated frog.		

	4. Charts showing comparison of the nervous system with a telephone exchange.		
Sense organs (important ones) Nose. Eye. Ear.	Model of eye and chart showing structure of eye and vision defects. Filmstrips on vision. Model and chart.		Visit to Ear, Nose, Throat clinic and Eye clinic.
Human machine.	Charts representing human body as a machine.		
(*b*) Health and disease: common diseases: common cold and cough, small-pox, cholera, dysentery, typhoid, malaria; their causes, spread and prevention.	Chart of disease-causing bacteria. Charts and specimens of stages of life-history of malarial mosquito and house-fly.	Preparing health charts and posters. Planning a Health Exhibition (Group Project).	Visit to a Health Centre. Destruction of the mosquito and house-fly in and around the school.
Natural and acquired immunity. Inoculation and vaccination.			Organization of a sanitation camp having a medical unit, a sick room and a First Aid Centre.
(*c*) Food in relation to health. Different kinds of food.	1. Tests for starch, sugar, fat and protein. 2. Chart of vitamins present in different food-stuffs.	Project: Testing common foodstuffs for their constituents.	
Value of each kind of food. Balanced diet.	3. Charts showing energy value of common food-stuffs.	Project: Exhibition on balanced diet for different age groups.	

APPENDIX II

GENERAL SCIENCE SYLLABUS FOR SECONDARY SCHOOLS IN WEST BENGAL

Class IV

1. Cultivation of vegetables of various types—and study of conditions which favour their growth.

2. Leaf—simple (e.g., mango) and compound (e.g., rose)—how fixed to stem. Recognition of common trees by their leaves, fruits and twigs. Fruits, juicy and dry. Collection of fruits under kinds (e.g., paddy, pea, mango, papaya, cucumber, lemon, apple, custard-apple, jack-fruit, etc.) and under methods of dispersal (of seeds by wind, by water, by animals, etc.). Collection of leaves under 'simple' and 'compound' and pressing and mounting them in scrap books.

3. Bird study to continue—their song, seasons of singing, habits, appearance, etc. Collection of pictures of birds and their nests and eggs.

4. Study of common garden creatures—snails, earthworms, spiders, wasps, etc. Earthworm—what it does to the soil.

5. Talks on peculiar animals which children do not see in their environment—the countries they live in. Visits to the zoo, if possible.

6. Lesson on one member of each of the following families; mammals, reptiles, fish, amphibia, insects.

7. Social life of ants and bees. Observation of ants' nests, and ant-hills of white ants. Bee-keeping.

8. Making of weather charts to continue.

9. Beginnings of the simple study of the human body.

10. Disposal of night-soil. How to utilize it. How to utilize cowdung, urine, etc.

11. Group activities of the type: organizing a nature club, a farmers' club and preparing a farmers' bulletin.

Class V

1. Functions of root, stem, leaf, and flowers. Parts of flower—descriptions of ordinary flowers like *jaba* (china-rose) *aparajita* (*Clitoria ternatea*) and experiments with them. Collection of flowers and preparing specimens. Collection book of flowers. Pollination. Trees and plants and their branching. Observation and examination of small branches and twigs. Experiments with bark, twigs and buds. Observing the changes of a partially sub-merged branch in water.
2. Harvesting and storage of crops.
3. Life-history of butterfly, silk-worm, mosquito, frog, ant and bee.
4. Simple consideration of the human body.
5. Observing the heavens:
   (*a*) Different kinds of clouds, with sketches. Dew, its clouds and rain. Sun, a bright star, source of light, its work.
   (*b*) Moon, phases of the moon, work of the moon. Pole star, Orion, Ursa Major, Cassiopeia in different seasons at particular hour in the evening sky.
   Venus, observing the Milky Way, sketch.
   Eclipses of sun and moon, elementary discussion.
   Weather chart of the different seasons.
6. Different kinds of soil, different ingredients. Increasing fertility of the soil by the use of manures such as cowdung, human excreta, decomposed leaves, etc.
7. Observation of agricultural fields and ponds.
8. The following subjects to be taught in reference to hygiene:
   (*a*) Air; wind; properties of air; constituents of pure and impure air; part played by plants in purifying impure air; the air in closed and crowded rooms. Ventilation, necessity and methods. Respiration.
   (*b*) Water; properties of water, its usefulness to plant

and animal life; constituents of pure and impure water, diseases spread by contaminated water; purifying wells, tanks, and river water in villages; tube wells; hard and soft water.

(c) Malaria, cholera, typhoid, smallpox, tuberculosis. First-aid to injuries due to burns, drowning, rabies, snakebite.

9. Use of magnets, and electricity.
10. Specimen collection books to be prepared as above.
11. Nature study.
12. Farmers' association.
13. Farmers' bulletin.

Class VI

1. Simple stories concerning scientific discoveries.
2. (a) Earth; how formed; its crust; simple types of rocks. Volcanoes and earthquakes. Minerals and other substances found inside the earth.
   (b) Air, water, atmosphere.
3. Life on earth; cycles of water; oxygen and carbon; identification of important or distinctive forms of life, such as vertebrates, invertebrates, mammals and non-mammals.
4. Simple ideas concerning heavenly bodies—sun, stars, planets, satellites, particularly moon, eclipses.

Classes VII and VIII

A. Air

1. What is air made of? Simple experiments for detecting oxygen and carbon dioxide in the air. Air contains mainly 1/5 volume oxygen and 4/5 volume inactive gas named nitrogen including traces of CO_2:

Experiments: (a) lime water experiments.

(b) lime water and alkaline pyrogallic in 18″ tubes, open

one in water and in the other put lighted taper which will go out immediately.

(c) burning candle.

2. Respiration : The air in relation to living objects; living objects suffocate in air without oxygen.

3. Rusting of iron :

(a) uses up oxygen from the air;

(b) needs both oxygen and water.

4. Combustion :

(a) burning substances use air,

(b) respiration,

(c) compare combustion and rusting.

5. (a) The main principles involved in ventilation. Its role in the health of man.

(b) Methods of ventilating a room and a kitchen.

(c) Hot air rises and cool air sinks.

(d) Windmill as generator of energy.

B. Water

1. Sources of water. Purification of water (decantation, filtration, distillation and sterilization). Its importance to living objects.

2. Mechanical mixture and chemical compound. Some important properties of elements of air and water.

3. Solvent action of water.

4. Humidity, rain (water cycle in nature), cloud, fog, dew and snow.

5. Hard and soft waters. Methods of softening hard water.

6. Water-mill and dams as generators of energy.

C. Energy

1. Sources of energy including food. Machines such as engine or clockwork and living machine compared. (Very elementary.)

2. Heat. Sources of heat; sun, electricity, mechanical and chemical action.

3. Effect of heat : incandescence, burning—change of state and of size.
4. Thermometers (Centigrade and Fahrenheit scales).
5. Transference of heat by conduction, convection, radiation. Good and bad conductors of heat.
6. Light. Radiant energy, green colouring matter of leaves absorbs rays (photosynthesis).

D. Living Objects

1. Distinction between living and non-living. Differences between plants and animals. Broad classification of plants and animals.
2. Observations on the different parts of gram or pea, viz., root, stem, leaves and flowers, with their functions in general.
3. Study of simple plants and animals : yeast, amoeba and moss.
4. Human body : a general knowledge of the elementary structure and functions of the human body (digestive, respiratory and excretory system).
5. Some common diseases, viz., malaria, smallpox, cholera, scabies.
6. Accidents and first-aid : burns; sprain and fracture; cuts including haemorrhage; drowning and artificial respiration; bites of scorpions, snakes and rabid dogs.

School Final Examination

A. Air

1. Percentage composition of air; air has weight.
2. Barometer, air pressure in relation to weather, changes in the composition of air due to respiration, combustion and photosynthesis.
3. Buoyancy. Flight of balloons with hydrogen gas.
4. Respiration, combustion and rusting to be discussed elaborately.

B. WATER

1. Composition of water. How water is formed. The town and rural water-supply. Water finds its own level (origin of spring): pressure depends on head of water. How is water polluted and purified ?
2. Volume, weight, mass and density. Archimedes' principle; simple idea of specific gravity.
3. Air and water in relation to life.

C. SOME METALS AND ALLOYS IN COMMON USE

1. General knowledge of copper, aluminium, iron, zinc, lead, mercury, brass and bell-metal.

D. SOME USEFUL SUBSTANCES AND THEIR CONSTITUENTS

1. Sodium carbonate, baking powder, soda water, sodium chloride, alum, vermilion, cement, lime, smelling salts.

E. LIGHT AND ITS EFFECTS

1. Sources of light.
2. Straight-line propagation of light, shadows, eclipses.
3. Reflection by plane mirror.
4. Refraction.
5. Convex lens, focus and focal length (magnifying glass, burning glass).
6. The prism, spectrum; colours.
7. Light and its effects on plant growth.

F. SOUND

1. Always caused by vibrations; medium of propagation: its velocity compared with velocity of light (thunder and lightning).

G. HEAT AND ITS EFFECTS

1. Sources of heat (sun, electricity, chemical and mechanical energy).

2. Effects of heat; expansion of solids, liquids and gases, evaporation and boiling.

H. Energy

1. Lifting weights by machines: (*a*) pulleys, (*b*) inclined planes, (*c*) muscles as levers.
2. The steam engine: heat energy changed to mechanical energy.
3. Magnetism, loadstone, artificial magnet, mariner's compass.
4. Electrical energy; electric battery—chemical energy to electrical energy; dynamo—mechanical energy to electrical energy.
5. The electric current and its effects—physiological, chemical, magnetic, thermal; electric bell; telegraph.

I. Some Aspects of Living Objects

1. The cell—protoplasm : its chemical and physical nature.
2. Plant study. Study of pea including its seeds and germination; pollination of flowers; fruit formation and seeds.
3. Dispersal of seeds and fruits in general.
4. Animal study. Study of earthworm, fish, toad, including its metamorphosis, mosquito, house-fly.
5. Human body. Consideration of human body in general, specially touching upon circulatory, muscular and nervous systems. (A general knowledge of the elementary structure and functions of the human body is taken for granted.)
6. Effects of defective and dirty drains and polluted air on health.
7. Air- and water-borne disease—influenza, measles, tuberculosis, dysentery, typhoid.
8. Immunity, vaccination, inoculation.

APPENDIX III

SYLLABUSES IN METHODS OF TEACHING SCIENCE IN PUNJAB, DELHI AND RAJASTHAN UNIVERSITIES

B.T. Class, Punjab University

1. Aims and objectives of science teaching particularly emphasizing the following—
    (a) To excite interest in nature.
    (b) Modern inventions.
    (c) Scientific attitude.
    (d) Scientific principles.

Place of science in school curriculum.
Developing the scientific attitude (counting, measuring, weighing and classification).

2. Methods of teaching.

Lecture method.
Demonstration method, conduct of a demonstration lesson.
Historical method.
Concentric method.
Topic method; scientific lessons from common things e.g., a bicycle, a well, a pond.
Heuristic method.
Assignment method.
Project method (e.g., field collections and surveys). Choice of a method.
Conduct of a practical class.

3. Equipment of the classroom and laboratory.

Combined lecture room and laboratory room.
Type and arrangement of different furniture and fittings.
Science Library.
Science Museum—its organization, labelling of specimens with brief informative notes.
Charts, diagrams and pictures.

First-aid box.

4. Curriculum. Making of science curriculum for different stages. Study of science curriculum in the Punjab for the Primary, Middle and High Classes. Schemes of work, their preparation and method of working out.

5. Apparatus and chemicals.

Selection, purchase, arrangement, care and overhauling of apparatus.

Co-operation of students out of school hours for this job. Home-made apparatus.

6. Audio-visual aids in science teaching such as charts, diagrams, and pictures from books, films, filmstrips, slides, gramophone, radio; excursion to places of scientific interest.

7. Correlation of science subjects with one another, with other school subjects and with daily life.

8. Textbooks—Their functions, selection of science books for different stages.

Laboratory notebooks.

Laboratory manuals.

Record of laboratory work.

9. Examination—Written and Practical.

New type, that is, objective type of tests.

Maintaining the record of the progress of students.

10. Planning and writing of lesson notes.

11. Other points—

(a) Time-table of the middle and high stages.
(b) Distribution of theoretical and practical periods.
(c) Science master's diary and notebook, how to maintain it.
(d) Home task, supervision and correction.
(e) Type of science stock registers and their upkeep.
(f) Inspection of a science department.
(g) Scientific hobbies—Importance and introduction.
(h) Organization of scientific society in school.

Practical

1. Making charts and models.
2. Developing the designing and inventive faculty of a child from an early age by thinking out improvements in ordinary household articles, for example, fitting an electric bulb in a Doli, additional fittings in a chair or a table which will increase its usefulness, making a water wheel, using a small electric motor for lifting weight or working a small wheel.
3. Experiments to demonstrate to a class a topic from the science syllabus of high classes.
4. Diagrams on the blackboard and charts illustrating various experiments showing the working of scientific instruments etc.
5. Drawing up a scheme of lessons of scientific topics for the secondary department with notes of lessons.
6. Drawing up assignment on topics from the science syllabus of high classes.
7. Drawing up laboratory instructions on topics included in the Practical Syllabus of the high classes.
8. Manipulation of a magic lantern and a filmstrip projector.
9. Preparation of soap, hair oil and ink.

Teaching of General Science, B. Ed. Class, Punjab University

1. The aim and value of science teaching: scientific methods and their applicability. Developing of scientific attitude. General science and science in everyday life. The place of general science in the school curriculum.
2. Teaching methods: The lecture-demonstration method. Heuristic method and the assignment method. The topic method. The historical method and the concentric method. The choice of a method. The aim, value and conduct of laboratory work, conduct of a lesson demonstration.
3. Equipment: type of classroom and laboratory. Combined

laboratory and lecture room. Kind and arrangement of furniture and fittings. Water-supply and drainage.

Apparatus: selection and purchase, arrangement and care of apparatus, co-operation of students out of school-hours for this work, home-made apparatus, science library.
4. Audio-visual aids in science teaching: charts, diagrams and pictures, slides and films, gramophone and radio, excursions to places of scientific interest.
5. Curriculum: variation in curriculum to meet the needs of scholars at different stages. Curriculum in the Punjab for the primary, middle and high classes, place of nature study and general science in the curriculum, their aim, scope and method.
6. Correlation of science subjects with one another, with crafts and social and physical environments.
7. Textbooks and their functions, scheme of work, their preparation and methods of working out. Planning of lesson notes.
8. Time-table in the middle and high stages, distribution of theoretical and practical periods. Science master's diary and notebook, home task, supervision and correction, laboratory notebooks, laboratory manuals, registers and their upkeep, laboratory servants. Examinations, written and practical. Inspection of science department, scientific hobbies. Organization of scientific societies in the school.
9. Maintenance of students' progress records and evaluation of their work.

Practical

1. About a dozen experiments to illustrate methods of demonstrating to a class topics from the science syllabus.
2. Educational handwork and its use in repairing and making simple apparatus. Improvising science apparatus.
3. Making charts and models.
4. Waxing of tables, cleaning of glass, brass and iron apparatus and polishing wooden apparatus.

5. Diagrams on the blackboard and charts illustrating various experiments showing the working of scientific instruments, etc.
6. Drawing of a scheme of lessons pertaining to scientific topics.
7. Preparation of soap, ink and disinfecting fluids.

Teaching of Science, B. T. Class, Delhi University

1. The place of science in schools.
2. Social functions of science.
3. The aims of science teaching.
4. Scientific method; characteristics. Examples and limitations.
5. The reasons for including physics and chemistry or biology in the curriculum.
6. Construction of the syllabus.
7. The organization of the school laboratory.
8. Individual and demonstration methods.
Benefit from heuristic theory—its influence—criticisms.
9. The use of diagrams, charts, models.
10. Basing the science course on the environment.
11. School projects.
12. (*a*) A library as an essential part of a science teaching programme.
 (*b*) Visits to places of scientific interest.
13. Specialization in science.
14. The methods of teaching physics and chemistry or biology. Preparation of lesson notes. Advantages of having a plan.
15. The science teacher.

Special Method Course in Physics and Chemistry, Rajasthan University.

Theoretical

1. Place of science in the school curriculum.

2. Methods of teaching science with special reference to:
   (*a*) The heuristic and laboratory methods.
   (*b*) The concentric method.
   (*c*) The problem method.

3. The science room and the laboratory; their equipment.

4. Curriculum in science.
Syllabus for middle, high school and intermediate sections.

5. Instruction in the classroom—experimental, demonstration.

6. Instruction in the laboratory—value of laboratory work, notebooks, technique of laboratory management.

7. Teaching of physics and chemistry, aims, methods, subject matter, correlation with other subjects, application to everyday life.

8. Science teacher—his qualifications and preparation, science library.

9. Modern physics and chemistry laboratory—need of Indian schools, and method of meeting this need.

Sessional Work

1. A course of 15 typical experiments from the high school and intermediate syllabus in physics and chemistry.
2. Elementary glass blowing: fitting up apparatus.
3. Preparation of a piece of simple apparatus involving wood-work.
4. Preparation of models, charts, graphs, etc.
5. Some useful laboratory arts, preparation of varnishes, silvering glass, electroplating, cutting of glass-tubes, plates and rods; cutting of metal sheets; simple soldering; replacing of electrical fuses.
6. Study, manipulation and use of any *three* of the following:
   (*a*) The gas plant.

(*b*) The optical lantern and epidiascope.
(*c*) The motor and dynamo.
(*d*) Electric bell installation.
(*e*) Electric light installation.
(*f*) Telephone installation.

7. Excursions to places of scientific interest.
8. At least four essays on the teaching of physics and chemistry in Indian schools.
9. Planning of lessons on the topic method.

APPENDIX IV

SPECIMENS OF LESSON NOTES

(a) Atmospheric Pressure

Aim: To teach that air exerts pressure in all directions; the method of measuring this pressure; and the application of atmospheric pressure to daily life.

Previous knowledge: properties of matter; air a material body, air has weight.

1st Stage: Introduction.

Questions of the following type will be put to test previous knowledge:

(i) Name some important properties of matter.
(ii) How will you show that air has weight?

2nd Stage: Air exerts pressure in all directions.

Teacher will put a number of notebooks on the palm of the out-stretched hand of a pupil and ask him what he feels. He will increase the number of notebooks and ask again what he feels. He will put a pound weight, then a two-pound weight on the palm, and again ask what the pupil feels. He will thus educe that air exerts pressure due to weight.

The following experiments will be performed to show that air exerts pressure in all directions:

(i) With a funnel to which a piece of thin rubber is tied. The rubber is pressed inwards when air is sucked out of the funnel. This happens in whatever position the funnel is kept.

(ii) With a jar full of water, covered with a piece of paper at its mouth. The water does not fall when the jar is inverted.

(iii) Air is pumped out of an open bell jar mounted on the disc of an air-pump with sheet rubber tied on the end of

the bell jar. The rubber is pressed inwards and bursts with a loud noise after some time.

(iv) With Magdeburg hemispheres. (Anecdote of Guericke's experiment with hemispheres 18" radius being pulled apart by a team of 16 horses will be related and an illustration of it will be shown).

BLACKBOARD: Air exerts pressure in all directions due to its weight.

3rd Stage: Value of air pressure.

(i) The teacher will fit up a barometer and make the students observe that mercury falls by a few inches. The length of the column of mercury will be measured and with the help of judicious questions it will be educed that a column of about 30" of mercury is supported by the column of air.

(ii) The mercury in the tube will then be poured in a glass vessel already weighed and put on a dial scale. The movement of the needle will indicate the weight of the mercury. It will be shown that the weight is equal to about 7 lb. (tube of $\frac{1}{2}$" cross section area was taken).

BLACKBOARD: Air can support a column of mercury about 30" in height. Air exerts a pressure of about 14 lb. per square inch. A diagram of a barometer.

4th Stage: Applications to daily life.

(i) Sucking water or soda through a straw tube.
(ii) Placing a hollow key to the lip when air is sucked out of it.
(iii) Rise of water in a syringe.
(iv) Water-pump.
(v) Eye-dropper, etc.

5th Stage: Recapitulation.

(i) How does an elephant drink water through its trunk?
(ii) Why do lizards not fall?

(iii) Why do we not feel the considerable (50 tons) pressure of air?

BLACKBOARD SUMMARY:

(i) Air exerts pressure due to weight.
(ii) Air exerts pressure in all directions.
(iii) Air can support a column of mercury 30″ in height.
(iv) Air exerts a pressure of about 14 lb. per square inch.

(*b*) CONVECTION IN LIQUIDS

Aim: To teach pupils how liquids get heated and some applications of this process to daily life.

Previous knowledge: Pupils know how solids get heated.

1st Stage: Introduction.

Questions such as the following will be put to test the previous knowledge of the class:

(i) When one end of a poker is put in fire what happens to the other end?

(ii) In what way has heat reached the other end?

(iii) Can heat travel in water in the same way?

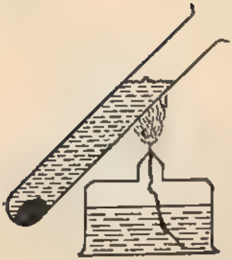
The teacher will perform an experiment (sketch A on the next page). He will fill a test tube with water and place a pebble coated over with wax at the bottom of it. He will place the tube over a burner so that the flame heats the top part of the tube and not the pebble which is thus farthest from the flame. From the experiment he will educe that water is a bad conductor of heat.

He will then ask: 'How do we heat water in our homes?' 'Where do we put fire?'

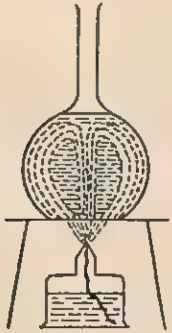
BLACKBOARD: Water is a bad conductor of heat (also the sketch).

2nd Stage: The process of convection.

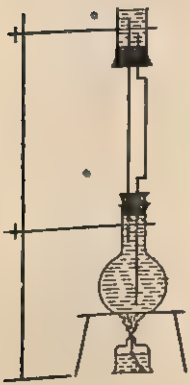
The teacher will heat some water in a flask and put a



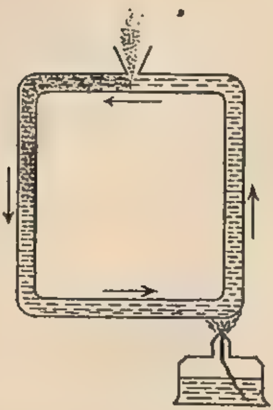
A



B



C



D

few crystals of potassium permanganate in the flask (sketch B). He will ask the boys to observe the coloured water rising from the centre and going down the sides. He will explain this and with the help of judicious questions educe the process by which liquids get heated. This is called convection.

Blackboard: Definition of convection as educed from the class (also sketch of the apparatus).

3rd Stage: Applications of convection.

(i) The experiment sketched in C will be shown. Coloured water from the lower flask will be seen rising up the straight tube to the top of the upper flask and uncoloured water from the upper flask coming down the bent tube. The heating of rooms by hot water pipes will thus be explained.

(ii) Formation of currents will be explained with the help of the experiment shown in sketch D.

(iii) Water will be boiled in a paper bag and it will be explained why the paper does not catch fire for some time.

4th Stage: Recapitulation.

(i) Describe the process by which liquids get heated.

(ii) In what respects does convection differ from conduction?

(iii) Name some applications of the process of convection to daily life.

Blackboard Summary:

(i) Water is a bad conductor.

(ii) Convection is the process by which liquids become heated by the actual movement of their particles due to difference of density.

(iii) Uses of the process of convection in daily life: (a) heating rooms by hot water pipes; (b) formation of ocean currents.

(c) A First Lesson on Magnetism

Aim: To teach the class the forms, properties and uses of a magnet.

Previous knowledge: Pupils are familiar with a horse-shoe magnet, and know its property of picking up iron objects.

1st Stage: Introduction.

A small horse-shoe magnet will be shown to the class and the following questions put:

(i) What is this?
(ii) Do you know anything about it?
(iii) What is its shape?
(iv) What is it made of?
(v) Have you seen a magnet of any other shape?

2nd Stage: Magnet and its forms.

(a) Different forms of magnets will be shown and their names will be told; (b) Brief history of the discovery of a loadstone will be narrated. (The anecdote of the shepherd and his crook). Explanation of the word 'magnet' will be given; (c) Classification of magnets into natural and artificial.

3rd Stage: Properties.

The following properties of magnets will be illustrated by experiments:

(i) Attract iron filings.
(ii) When suspended freely always point north and south. (Explanation of word 'loadstone' will be given.)
(iii) The force of attraction is greatest at the ends (idea of poles and their names will be given at this stage).
(iv) Like poles repel and unlike poles attract (primary law of magnetism). Repulsion is the sure test of magnetism.

4th Stage: Application of the properties of magnets.

(i) Separation of iron filings from other objects—brass, powdered glass, snuff, clay, wheat; removal of pieces of iron from eyes of workers; lifting scrap iron with the help of a magnetic crane, etc.

(ii) Compass to find directions.

BLACKBOARD SUMMARY:

1. Forms of magnets and their kinds.
(i) Horse-shoe magnets.
(ii) Bar magnets.
(iii) Magnetic needles.
(iv) Loadstone.

The first three are artificial, and the fourth natural.

2. Properties of magnets.
(i) Attract iron filings.
(ii) When suspended freely they point in a north and south direction.
(iii) The force of attraction is the greatest at the poles.
(iv) Like poles repel each other and unlike poles attract each other. This is called the primary law of magnetism.
(v) Repulsion is the sure test of magnetism.

3. Uses of magnets.
(i) In separating iron filings from other objects.
(ii) In finding directions.

(*d*) SODIUM AND ITS CHIEF COMPOUNDS

Aim: To teach the physical and chemical properties of the metal sodium, and the names and common uses of some of its important salts.

Previous knowledge: Boys know the distinctive features of metals. They have heard the names and know the common uses of washing soda, caustic soda and common salt.

1st Stage: Introduction.

Questions of the following type will be put to test previous knowledge.

(i) Name the chief characteristics of metals.

(ii) Which important properties distinguish metals from non-metals?

(iii) Name an element which though lighter than water is yet a metal. Why do you suppose it to be a metal?

(iv) To what use do we put caustic soda, washing soda and common salt?

Teacher will then declare the aim: 'We shall learn more about the metal sodium and substances like caustic soda, washing soda, etc. today.'

2nd Stage: Some properties of sodium.

A freshly cut piece of sodium will be put on a filter paper and passed round and its metallic lustre shown; a boy will be asked to cut another piece and its soft waxy nature brought home. Similarly its lightness and the effect of exposure to air will be shown and why it is kept under kerosene oil.

BLACKBOARD: Sodium is a light, soft metal. When freshly cut it shows a metallic lustre. When exposed to air it soon gets tarnished. It floats on water and soon disappears, so it is kept under kerosene oil.

3rd Stage: Action of sodium on water.

Experiment, to show that hydrogen is produced when sodium acts on water, and that an alkali is also produced which turns red litmus solution blue, will be shown. A glass tubing of slightly wide bore will be supported in a beaker containing red litmus solution. One or two small bits of sodium will be dropped inside the tube. The gas coming out of the tube will be ignited with a match. The litmus solution inside the tube will be seen to have turned blue.

BLACKBOARD: When a piece of sodium is thrown on water it swims around with a hissing sound, combines chemically with water, giving hydrogen and producing an alkali that turns red litmus blue.

4th Stage: Some common compounds of sodium and their uses.

Samples of common salt, caustic soda, washing soda, and sodium bicarbonate will be passed round, and the class will be told that all of them are compounds of metal sodium. Boys will be asked some of the uses of these salts and other uses will be told to them, and also their chemical names

BLACKBOARD: (i) Common salt—sodium chloride, used for eating, curing hides and fish, preservative in achars and other things, in the making of washing soda and caustic soda, and preparation of hydrochloric acid.

(ii) Washing soda—sodium carbonate, used for washing, softening hard water and making caustic soda.

(iii) Sodium bicarbonate—used in medicine and baking powders.

(iv) Caustic soda—sodium hydroxide, used in making soap and paper.

5th Stage: Recapitulation.

(i) Why is metal sodium not kept under water or in an empty bottle?

(ii) Name the chief physical and chemical properties of sodium.

(iii) Name the uses of salt, soda and caustic soda.

BLACKBOARD SUMMARY: As above.

(*e*) PREPARATION AND STUDY OF THE CHIEF PROPERTIES OF CARBON DIOXIDE GAS IN THE LABORATORY

Aim: To get pupils to fit up the apparatus for the preparation of carbon dioxide in the laboratory, prepare the gas and study its chief physical and chemical properties.

Previous knowledge: The teacher has already taught the gas in his demonstration period.

Procedure: The teacher will call the class round the demonstration table and will ask them the following questions:

(i) How is carbon dioxide prepared in the laboratory?
(ii) Is it heavier or lighter than air?
(iii) Is it soluble in water?
(iv) How will you collect this gas?

He will then draw the attention of the class to a sketch of the apparatus already drawn on the blackboard and ask them to fit the apparatus accordingly. (See diagram VI at the end of this book.)

The following precautions (written on the blackboard previously) will also be emphasized:

(i) The apparatus should be tested to be air-tight.
(ii) The thistle funnel should dip in the liquid.
(iii) Water should be just enough to cover the pieces of marble.

The boys will then be asked to fit up the apparatus. The teacher will go round giving individual help. While the boys are busy collecting the gas, he will put down on the blackboard a list of experiments to be performed and properties to be tested by the boys as given below:

(i) Colour and smell.
(ii) Action on litmus solution.
(iii) Heaviness.
(iv) Action on a burning taper.
(v) Action on lime water for a short time and for a long time.

He will ask them to record their work in the following tabular form:

Experiment	Observation	Inference

When the boys are busy performing the experiments to study the properties of gas, the teacher will go round, give individual help and tick off portions of written work examined.

At the end of the period he will sign the notebooks and supervise the return of clean apparatus to the cupboards.

Note: In the specimens of lesson notes given above, the apparatus required has not been shown. Pupil teachers should always give in their notes the list of apparatus required. This list may be put below the aim, under the heading 'apparatus'.

(*f*) Parts of a Flower and their Functions

Aim : To teach the pupils the various parts of a flower and their functions.

Aids : 1. A chart showing the various parts of a flower.
2. The model of a flower.
3. Actual specimens of flowers and buds.

Previous knowledge: Students have studied the various parts of a plant and their functions. They have also seen different kinds of flowers.

Testing previous knowledge : The following questions will be put to students in order to test their previous knowledge:

1. What are the various parts of a plant ?
2. What are the functions of the stem ?
3. Name the parts of a plant to which the stem gives rise.

Introduction : The following questions will be put to introduce the subject:

1. Why do we plant flowers in gardens ?
2. Name some flowers which are used in medicine.

The teacher will sum up their answers thus:

We use flowers for ornamental purposes and for medicine. Flowers grow into fruits and seeds which we eat. Flowers are therefore very important for us.

Announcement of the aim : Today we shall study in detail a flower and its parts along with their functions.

Presentation : An actual specimen of a flower will be distributed to each student and they will be asked to observe it starting from the base of the flower. A specimen lesson is shown on pages 164 and 165.

(g) Mosquitoes

Aim : To teach the students the four stages in the life-history of a mosquito, to tell them how to get rid of mosquitoes, and hence to teach the means of fighting malaria.

Aids :
1. Charts showing the different stages in the life of a mosquito.
2. A model showing egg, larva, pupa, and adult mosquito.
3. Actual specimens of life stages of the mosquito contained in bottles.
4. D. D. T., quinine, paludrine, mosquito-cream.

Previous knowledge: Students know the names of some common insects, harmful as well as useful and they have heard the name of malaria fever.

Testing previous knowledge : Questions of the following type will be asked to test the previous knowledge of the students:
1. Name some common insects.
2. Which insects are harmful and cause diseases ?
3. Which insect troubles you most at night ?

Introduction : The following questions will be put to introduce the subject:
1. When does malaria generally occur ?
2. Do you know how malaria is caused ?

Statement of the aim : The students will probably not be able to give a correct answer to question 2 above. The teacher

(*Please turn to Page 166*)

Matter	Method (Questions)	Blackboard Summary
1. The lowest part of the flower by means of which it is attached to the branch is called the pedicel. It is green in colour. It keeps the flower exposed to air and sunshine and carries food from the branch to the flower.	1. What do you see at the base of the flower ? 2. What is the colour of the stalk ? 3. What is the medium through which food is transported from the branch to the flower ?	1. The green stalk is called the pedicel. It serves to carry food to the flower.
2. The outermost whorl of the leaves is green in colour. Each leaf of this whorl is called a sepal. Sepals serve to protect the flower in its bud condition.	1. What is the colour of the outer whorl of leaves ? What is the function of the sepals ?	2. The green outermost leaves called the sepals serve to protect the flower in bud condition.
3. Next to sepals are a number of brightly coloured leaves in a whorl. These leaves are called petals. They give a pleasant smell. On account of the colour and smell of petals, flowers attract insects.	The teacher will ask pupils to remove the sepals and note that inside these are brightly coloured leaves. They are called the petals. Pupils will also be asked to discover whether the petals give any smell.	3. Next to the sepals are the brightly coloured and scented petals. They serve to attract insects.
4. Inside the petals there are stamens. These consist of anther lobes and filaments. The anther lobes possess yellow pollen. This is the male part of the flower.	The teacher will ask pupils to remove the petals and note the threadlike filament with the bag like anther cap at the top. They will be asked to touch the anther with their finger and note what happens to the finger.	4. Stamens consist of anther and filament. They serve as the male part of the flower.

Matter	Method (Questions)	Blackboard Summary
5. In the centre of the flower there is the carpel or pistil. It has three parts: a. Ovary b. Style c. Stigma This is the female part of the flower.	The teacher will ask pupils to remove the stamens and see the carpel or pistil. He will draw attention to the difference in its shape at the base, middle and the top. The lower swollen portion is the ovary, the middle is the style and the head is the stigma.	5. The carpel: It has three parts: i. Ovary ii. Style iii. Stigma It serves as the female part of the flower.

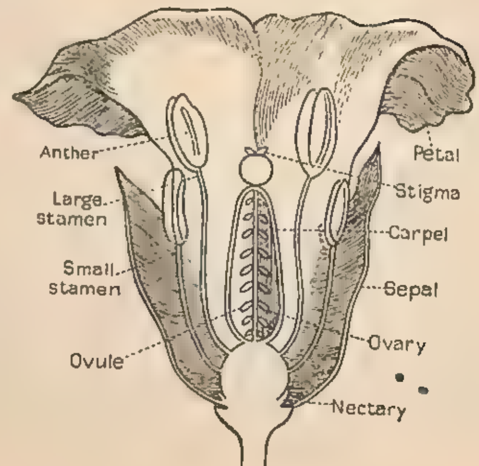
Recapitulation: The lesson will be recapitulated with the help of questions by showing the model of a flower, and by explaining the diagram on a chart. Questions of the following type will be put in order to ensure proper grasp of the lesson:

1. What are the parts of a flower ?

2. Give the functions of each part.

Blackboard Summary: As above.

Application and Home-work: Students will be asked to collect flowers of different colours, note their various parts, and preserve them in an album.



will therefore tell them that the mosquito is responsible for spreading malaria. He will then announce the aim: Today we shall study the life-history of a mosquito, how to get rid of mosquitoes and how to get rid of malaria.

Presentation : I. Mosquitoes take a heavy toll of human life every year by spreading malaria. The disease spreads during the rainy season when mosquitoes abound. Mosquitoes breed in dark dingy places under shelves and furniture, in marshy places and on standing water.

II. The students will be told that there are two kinds of mosquito—Anopheles and Culex. Their characteristics will be taught by reference to models and the chart showing diagrams of the two kinds. The characteristics taught will be summarized on the blackboard.

III. Destruction of mosquitoes: In this connexion the following points will be educed from the students by suitable questions and will be put on the blackboard.

(i) To prevent mosquitoes breeding we should not tolerate stagnant or standing water near our houses.

(ii) We should sprinkle kerosene oil on stagnant or standing water to kill the larvae.

(iii) We should spray D. D. T. or Flit in our rooms in order to kill mosquitoes.

IV. How to save ourselves from malaria ? The following points will be educed and put on the blackboard:

(*i*) To guard ourselves from mosquitoes we should use mosquito nets at night. We should use mosquito oil or cream and, as far as possible, should not allow any part of the body to be exposed to the bites of mosquitoes.

As a safeguard against malaria we should take quinine during the malaria season. Two tablets of 5 grains each per week taken regularly may be considered effective for this purpose.

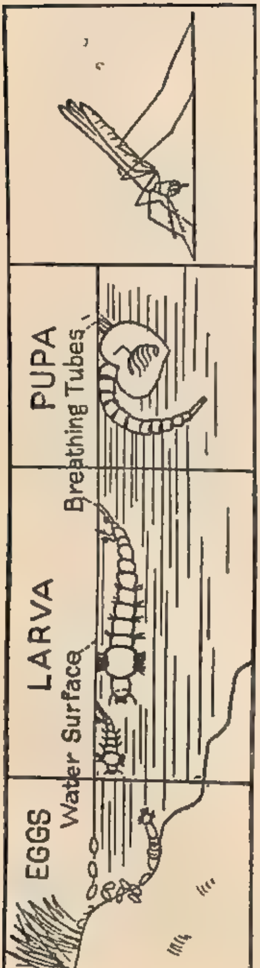
Application : By questioning, teach that (i) we should not live in dirty, dingy and dark places and should avoid living near marshy places, ponds, stagnant and standing water.
(ii) We should fill any pits in our neighbourhood with earth, we should use mosquito nets at night, and mosquito oil or cream on the exposed parts of the body.
(iii) We should sprinkle D.D.T. or Flit in ourhouses regularly.
(iv) We should take quinine or paludrine during the malaria season as a precautionary measure.

Recapitulation : The lesson will be recapitulated with the help of questions and by explaining the diagrams of mosquitoes on a chart. Suitable questions will also be put to ensure that the points taught have been grasped by pupils.

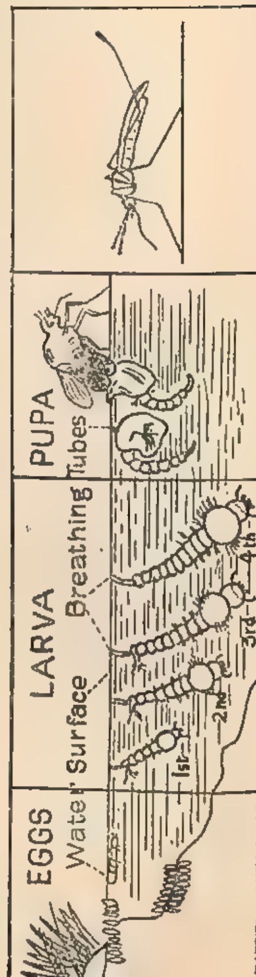
Blackboard Summary :
(i) Characteristics of the two kinds of mosquitoes.
(ii) Destruction of mosquitoes.
(iii) Precautions to save ourselves from malaria.

Home Task : The students will be asked not only to observe for themselves the precuations which have been taught to save ourselves from malaria, but also actively to put them into practice in their own homes.

On pages 168 and 169 will be found pictures of the Anopheles and Culex mosquitoes, together with a list of their different habits.



ANOPHELES



CULEX

Anopheles	Culex
1. Eggs are laid in water. They float singly or in groups.	1. Eggs are laid in water. They float as one compact mass.
2. The larva lies parallel to and just beneath the surface of water.	2. The larva lies with head downwards in water.
3. The pupa has a shape like a letter C.	3. The pupa has a shape like a letter C.
4. The mosquito lies in a position slanting to the surface.	4. The mosquito lies in a position parallel to the surface.
5. The adult has spotted wings.	5. The wings of the adult are not spotted.
6. The female anopheles is responsible for the spread of malaria.	6. It does not spread malaria.

APPENDIX V

QUESTIONS

A—Methods of Teaching

1. 'Essentially, the heuristic method is intended to provide a training in method; knowledge is a secondary consideration.'

Comment on this statement and say how far the introduction of this method is desirable for teaching science to boys of high classes.

2. What do you consider to be the essential factors for the success of the assignment method of teaching science? Discuss.

3. What value do you set upon the assignment system of teaching science? Why? What principles will guide you in preparing assignments and in running this system successfully in schools?

4. 'If the Almighty were in the one hand to offer me truth and, in the other, search after truth, I would humbly but firmly choose search after truth.' Explain the saying and write your views on the heuristic method.

5. Describe the method of teaching nature study such as you would follow if you were teacher-in-charge of the subject.

6. At what stage in the teaching of science do you think that logical reasoning should be insisted on? Why?

7. Huxley said: 'That great end of life is not knowledge but action.' Explain this saying, and discuss the scientific method of education to reach this end.

8. How would you encourage a spirit of inquiry in a chemistry lesson, say on charcoal?

9. What is the difference between scientific method and scientific fact? Which would you emphasize in your science teaching?

10. Give instances of 'verification' experiments that may be of value. What is your experience of boys 'cooking' their experiments in science?

11. State briefly the advantages and disadvantages of the demonstration method of teaching science in school.

12. Discuss briefly the various methods of teaching science, also the outstanding advantages and disadvantages of each.

13. The heuristic method of teaching science is not a practical proposition, but many of the advantages of the heuristic method are found in other methods: (i) assignment method; (ii) demonstration method. Discuss.

14. The teaching of science may be (a) formative, (b) informational, (c) both formative and informational. Which is best for the Punjab schools? State reasons briefly.

15. Discuss the relative merits of the concentric, heuristic and the topic method for teaching science in the lower middle, upper middle and high schools.

16. The assignment method fails in many cases in giving a sound scientific training to a boy. Discuss.

17. If there is one thing likely to shake the confidence of pupils in their science teacher, it is his failure to make his experiments successful. How will you ensure success in experiments?

18. State briefly the essentials of successful experimentation by the teacher in a lesson demonstration. Do you think that the main principles of a science subject are likely to be obscured if application and illustrations are too freely used? If so, what is your remedy?

19. Explain how you will demonstrate to your students the truth of the law of conservation of mass.

20. Give briefly the essentials of successful demonstration by a science teacher.

21. Why should experiments be performed as freely as possible in a lesson demonstration and what do you hope to achieve by experimentation?

22. How would you give your class a clear idea of chemical action? How far and when would you like to introduce symbols and formulae in your chemistry teaching?

23. 'Experiments should not be mere occasional efforts to substantiate some of the facts told by the teacher to his class.' Discuss the above statement with reference to the place of experimental work in science teaching.

24. Give a brief outline of the procedure you would adopt for a demonstration lesson on barometer or expansion of solids by heat.

25. How would you demonstrate to the class:

(i) The great affinity of hydrogen for chlorine.
(ii) Oxidizing action of nitric acid.
(iii) Good radiators are good absorbers.
(iv) Boiling point of water depends on pressure.

26. Comment on the statement: 'Success of science teaching in the high classes depends on a happy combination of demonstration table and laboratory training.'

27. Draw diagrams suitable for blackboard to illustrate air pump, electric bulb with a cell and a switch, and electric bell connected through a bell push.

28. An experiment like an act has three branches, to 'conceive', 'to do', and 'utilize'. Explain by example.

29. Write short notes on:—(*1*) home-made apparatus; (*2*) science libraries; (*3*) school museums; (*4*) charts and diagrams in a science laboratory; (*5*) questioning and its place and form; (*6*) use of a teacher's voice; (7) theoretical work should always come before practical work; (*8*) type and use of diagrams; (*9*) arrangement of apparatus in a science department; (*10*) science periods in a school time-table (*11*) teacher's own scheme of work; (*12*) examination of notebooks by teachers; (*13*) value of laboratory work for general education; (*14*) necessity or otherwise of keeping science teaching in touch with everyday applications of the principles of science; (*15*) cinema

in science teaching; (*16*) school master's diary and scheme of work; (*17*) boy's laboratory records and demonstration lesson notes; (*18*) a science time-table in the high classes; (*19*) ordering of science apparatus; (*20*) the help that schoolboys can give in the upkeep of the school laboratory; (*21*) proper allotment of time to practical and theoretical in the school science time-table; (*22*) use of excursions; (*23*) utility of holding term examination in practical science; (*24*) making of an annual indent for apparatus and chemicals; (*25*) the true aim in preliminary teaching of science is not to give a mass of facts to the pupil but to train him in the right habit of investigating and of inference; (*26*) parrot has no place in science; (27) the place of hypothesis in science teaching; (*28*) (a) vocational instruction must be based on a foundation of general education; (b) vocational work so far as possible should include instructions in scientific principles on which industrial principles are based.

30. Write teaching notes on any one of:—(*1*) first lesson on sulphur; (*2*) preparation of hydrochloric acid gas; (*3*) laws of floating bodies; (*4*) principle of Archimedes; (*5*) first lesson on refraction of light; (*6*) preparation and properties of oxygen; (7) preparation of ammonia; (*8*) first lesson on electricity; (*9*) specific heat of iron; (*10*) first lesson on phosphorus, electric induction, iron and steel; (*11*) the effect of pressure on the boiling point of a liquid; (*12*) formation of images; (*13*) centre of gravity; (*14*) physical and chemical changes; (*15*) crystallization; (*16*) first lesson on sodium or magnetism; (*17*) expansion and contraction; (*18*) pressure of air; (*19*) water purification; (*20*) reflection; (*21*) properties and uses of carbon dioxide; (*22*) determination of dew point; (*23*) convection current in fluids; (*24*) distinction between mechanical mixture and a chemical compound; (*25*) Newton's laws of motion; (*26*) composition of water; (27) acids, alkalis and salts; (*28*) charcoal; (*29*) latent heat of water; (*30*)

evaporation and boiling; (*31*) inertia; (*32*) air pump; (*33*) neutralization of acids and alkalis; (*34*) levers; (*35*) hard and soft water; (*36*) copper; (*37*) allotropic forms of carbon; (*38*) composition of air; (*39*) three methods of propagation of heat; (*40*) barometer; (*41*) expansion of solids by heat; (*42*) distinction of solids, liquids, and gases; (*43*) electroplating; (*44*) siphon; (*45*) electro-magnet; (*46*) the three states of equilibrium; (*47*) first lesson on current electricity; (*48*) first lesson on heat; (*49*) Ampére's rule; (*50*) combustion and flame.

31. What are the special features of the concentric method? How is it superior to the problem method? Give examples to illustrate your answer.

32. Write out laboratory directions for a class of 20 ready to prepare hydrochloric acid gas in the laboratory.

B—Equipment

1. You are given a grant of Rs 3,000. How would you spend it on the equipment of a new school laboratory and science library?

2. You are put in charge of a newly built science laboratory in a high school. Enumerate with brief comments the steps you would take to equip the laboratory for efficient science teaching. (You can assume that the laboratory is a room about 45×25 ft., and classes of 40 boys each.)

3. Give the names and addresses of three British and three Indian firms who deal in science apparatus.

4. Describe the simplest but most convenient science laboratory that you would have in an ordinary school at the least expense.

5. What principles would you observe in the construction and equipment of a science classroom in a school?

6. In the setting up and running of a school science department, what suggestions would you offer which would

result in economy in expense without lowering the efficiency of teaching?

7. A science library should be an essential part of the equipment of every school where science is taught. Make out a list of the books on science from which you gained inspiration.

8. Discuss the utility of charts and blackboard sketches in a chemistry lesson. Which of them do you prefer, when and why?

9. Draw the plan of a combined demonstration and practical room indicating the position of almirahs, sinks, teacher's table and the blackboard.

10. As headmaster of a large school, what organization would you aim at for science teaching in your middle and high departments?

C—General

1. Make out a case for the introduction of science teaching in all schools.

2. Draw up a syllabus for practical work in nature study for primary classes.

3. What do you consider to be the aims of science teaching in schools up to matric standard? Do you consider that the present science teaching in the Punjab schools comes up to your ideals?

4. What do you think of the present everyday science syllabus for the middle classes?

5. You are sent to inspect the science teaching of a high school. Outline your procedure.

6. Science teaching in our schools is criticized as being textbookish and divorced from everyday life. What suggestions can you offer whereby this state of affairs can be improved?

7. What should, in your opinion, be the objective of good science teaching? State briefly how you would

attempt to achieve the ideal you are going to keep in view.

8. Give the scope of nature study and describe the principles you would follow in teaching this subject.

9. Illustrate, by means of examples taken from the curriculum of the matric examination, how to correlate science with other subjects.

10. Until recently science was not taught seriously in schools and was rather looked down upon as a subject fit only for the backward boys. What is the position now and why has the change taken place?

11. Discuss the desirability or otherwise of abolishing the science practical examination from the matriculation.

12. Natural science should be included in the general course of education of all up to the age of sixteen. If you justify this conclusion, what syllabus would you lay down for the course in general science for primary and middle classes? If not, give reasons.

13. What evil consequences flow from waste in the laboratory? How would you stop this waste to produce good results?

14. There are very great advantages in putting the teaching of mathematics and physics to boys up to the age of sixteen in the hands of the same master. It would improve the teaching in both subjects by giving point to the mathematics and precision to the physics. Discuss.

15. What are the requisites of a good book on physics and chemistry? What use would you make of the textbook in actual teaching?

16. Describe some of the accidents that generally occur in a laboratory, and state the procedure you would adopt in each case for relief.

17. Describe the form and contents of pupil's notebooks in practical work. When and how would you correct these notebooks?

18. How would you deal with poor results in practical

work? Write also a note on 'cooking' of results, its causes, effects and remedy.

19. What and how would you like to teach your brothers and sisters in your home with regard to carbon dioxide with *ordinary things* found in the bazaar or house?

20. What scientific hobbies would you encourage among your pupils? Why? Name some home-made scientific toys which illustrate part of M. &. S. L. C. Course and say how they can be made.

21. In what ways does science teaching foster habits of care, precision, systematic arrangement and initiative?

22. Set examination papers for the tenth class to serve as final test; written paper, 2 hours; practical paper, 2 hours.

23. What are the science teacher's natural aids in teaching? Discuss these, briefly indicating what you consider the order of their importance.

24. We aim to give our schoolboys a good general education up to matriculation stage. What part can teaching of science have in this attempt to impart a good general education?

25. In educating for leisure rather than vocational or utilitarian purposes, can science legitimately claim a place in the curriculum? If so, why?

26. The study of science as a school subject is certainly useful for community and individuals. Justify the above statement. Summarize the chief value of science as an important school subject.

27. A lesson in science should itself be scientific. Comment upon this.

28. Discuss the suitability or otherwise of the present syllabus of science for the Matric examination of Punjab University. How would you like it to be revised if at all, and why?

29. The claims of science for a place in the school curriculum are now well recognized. What has brought about

this victory? What in your opinion is the chief value of science as an important school subject?

30. Justify the statement that physics and chemistry claim the first place in post-nature-study science course.

31. 'Science should be made a compulsory subject up to the Intermediate stage.'

Comment on the above, giving an outline of the syllabus for the high school and intermediate classes.

32. What are the defects of the teaching of science in our schools? How should the teaching of science be made more realistic and useful?

33. What is the importance of excursions to places of scientific interest in science teaching? What points should a science teacher keep in view when planning such an excursion?

34. What are the claims of science as a school subject? What place in your opinion should be given to this subject in the primary school curriculum and why?

35. Name the special problems that generally arise in science teaching in secondary schools and say how you will solve these.

36. What use will you make of audio-visual aids in teaching science? Name some such aids and describe any one of them.

37. Draw up a list of lessons for the ninth class on the subject of 'Transmission of Heat'. Indicate what apparatus will be required to teach these lessons. Which of these apparatus can be home-made?

38. In the new syllabus for primary and middle classes of the Punjab schools, general science and everyday science have been made compulsory subjects. Do you agree with this? Give reasons for your answer. Also, give criticism, in general, of the syllabus laid down.

39. Discuss the educational value of (i) films (ii) slides (iii) radio (iv) gramophone records in connexion with science teaching.

40. A teaching aid, however good it may be, cannot replace a teacher. Discuss.

41. What is the educational value of science fairs and exhibitions? How would you organize one?

42. What part do hobbies play in the education of school children? What hobbies would you encourage in your pupils and how would you direct them?

43. What is nature study? Give reasons for including this subject in the school curriculum.

44. What are the defects of teaching science in our schools? How could the teaching of science be made more realistic and useful?

45. 'On the teaching of general science depends the mental and intellectual growth of our pupils.' Discuss the statement and narrate the evil effects of neglecting the study of general science as a core subject in higher secondary schools.

46. Prepare a list of about ten items of apparatus which can easily be improvised with simple materials and advantageously used in science teaching. Give details of construction.

47. 'It is important that the treatment of general science is kept broad by linking it with other school subjects.' Illustrate how you propose to carry out the suggestion if you are in charge of either middle school science or high school science.

48. 'The study of general science as a core subject in the school curriculum is certainly useful for community and individual.' Justify the statement. How will you ensure maximum benefit to a pupil from the study of general science?

49. It is a well-known fact that relatively few pupils have real talent for science and consequently have no interest in it. Comment on this and state what steps you would take to stimulate students' interest in science subjects.

50. In what ways does science foster habits of correct observation, reasoning and truth?

APPENDIX VI

LIBRARY LIST

Key to Publishers:—(1) George Allen & Unwin (1a) Appleton (2) E. Arnold (3) G. Bell & Sons (4) Ernest Benn (5) A. & C. Black (6) Blackie & Son (7) Blackwell (7a) Blue Ribbon Books, New York (8) Cambridge University Press (9) Cassell & Co. (10) Chapman (11) Constable (12) K. & J. Cooper (13) J. M. Dent (14) Foulsham (15) Ginn & Co. (16) John Hamilton (17) George G. Harrap & Co. (18) D. C. Heath & Co. (19) T. C. & E. C. Jack (20) Longmans Green & Co. (21) Macmillan & Co. (22) Methuen & Co. (23) John Murray (24) T. Nelson & Co. (24a) New Home Library, New York (25) Oxford University Press (26) I. Pitman & Sons (27) Routledge & Co. (28) S. P. C. K. (29) Seeley Service & Co. (30) Sidgwick & Jackson (30a) Sigma Books Ltd. (31) H. M. Stationery Office (32) University of London Press (33) University Tutorial Press (34) Ward Lock & Co. (35) Waverley Book Co.

PHYSICS

A.B.C. of Physics, by J. L. B. Taylor (16)
Assignments in Practical Elementary Science, by R. H. Whitehouse & Mabel Whitehouse (21)

Boys' Book of Wireless, by E. H. Robinson (9)

Chemical Amusements and Experiments, by C. R. Gibson (29)

Easy Lessons in Wireless, by R. W. Hutchinson (33)
Electricity and Electrical Magic, by V. E. Johnson (25)
Electricity as a Wizard, by C. R. Gibson (6)
Electricity of Today, by C. R. Gibson (29)
Elementary Physics, by M. McFairgrieve & J. T. Cundell (3)
Everyday Physics, by H. E. Hadley (21)
Exercises and Problems in Practical Physics, by G. N. Pingriff (3)

First Book of Physics, by L. Lownds (21)
First Course in Wireless, by R. W. Hutchinson (33)
Flying and its Mysteries, by V. E. Johnson (25)
Fundamentals of Physics, by Bowen C. Dees (24a)

Mechanics and its Mysteries, by V. E. Johnson (25)

New Experimental Science, by J. G. Frewin (25)

Our Good Slave Electricity, by C. R. Gibson (29)

Practical Elementary Science, by Dora Hussay (21)

Readable School Electricity, by V. T. Saunders (3)
Readable School Mechanics, by R. C. Fawdry (3)
Readable School Physics, by J. A. Cochrane (3)
Romance of Modern Electricity, by C. R. Gibson (29)
Romance of Modern Mechanism, by A. Williams (29)

Story of Electricity, by W. F. F. Shearcroft (4)

Textbook of Wireless Telegraphy and Telephony, A, by W. Greenwood (33)

Vacuum, by J. A. Cochrane (3)

Wireless Really Explained, by P. J. Risdon (14)
Wireless Questions and Answers, by P. J. Risdon (14)
Wonders of Electricity, by A. T. McDougall (26)
Wonders of Physical Science, by E. E. Fournier (21)

CHEMISTRY

A.B.C. of Chemistry, by N. R. Tripp (16)
Achievements of Chemical Science, by J. C. Philip (21)

Chemical Amusements and Experiments, by C. R. Gibson (29)
Chemical History of a Candle, by M. Faraday (13)
Chemistry and Chemical Magic, by V. E. Johnson (25)
Chemistry and its Mysteries, by C. R. Gibson (29)
Chemistry in Service of Man, by A. Findlay (20)
Chemistry of Today, by P. G. Bull (29)

Electrochemistry of Solutions, by S. Glasstone (22)
Everyday Chemistry, by W. Robinson (22)

First Book of Chemistry, by W. A. Whitton (21)
Fundamentals of Chemistry, by Monroe M. Offner (24a)

Joseph Priestley, by D. H. Peacock (28)

Makers of Science Series—Chemistry, by E. J. Holmyard (25)
Marvels of Chemistry, by A. T. McDougall (26)
Modern Chemists and their Work, by Christy Borth (24a)

Practical Chemistry, by E. J. Holmyard (3)
Practical Chemistry, by L. C. Newell (13)

Readable School Chemistry, by J. A. Cochrane (3)
Romance of Coal, by C. R. Gibson (29)
Romance of Modern Chemistry, by J. C. Philip (19)

Wonder Book of Chemistry, by J. H. Fabre (1)

BIOLOGY, PHYSIOLOGY AND HYGIENE

A.B.C. of Biology, by C. M. Yonge (27)
A First Biology, by S. Maugham & W. R. Sherriffs (10)

Biology, by E. R. & A. V. Spratt (33)

Food, by R. McCarrison (21)
Food, Health and Vitamins, by R. H. A. & V. A. Plimmer (20)

How our Bodies are Made, by R. M. Wilson (25)
Hygiene, by C. Rama Murti (21)

Introduction to Biology, by S. Maugham (4)

Life, by A. E. Shipley (3)

Our Bodies and How they Work, by E. M. Chubb (20)

Physiology and Hygiene, by Sir Ronald Ross (12)

Readable Physiology and Hygiene, by J. A. Campbell (3)
Readable School Biology, by O. H. Latter (3)

A School Course in Hygiene, by R. A. Lyster (33)
Study of Living Things, The, Books I, II and III, by H. W. Ballance (17)

Wonders of the Human Body, by M. A. Shuttleworth (32)

METHOD OF TEACHING

Class-room Science—(Teacher's Book) Vols. I, II, III, IV, by W. B Little (24)

School History of Science, by J. A. Cochrane (2)
Science in Education, by H. H. Cawthorne (25)
Science Teaching, by F. W. Westaway (6)
Scientific Method, by F. W. Westaway (6)
Suggestions for the Consideration of Teachers, by Board of Education (31)

Teaching of Chemistry in Secondary Schools, by A. Smith and E. H. Hall (20)
Teaching of General Science—Vols. I and II, by Science Masters' Association (23)
Teaching of Science, by F. Hodson (10)
Teaching of Science, by W. L. Sumner (7)
Teaching of Science in Schools, by John Brown (32)

Teaching of Science in Secondary Schools, by Science Masters' Association (23)
Teaching of Science in Secondary Schools in England, by Board of Education (31)
Teaching of Scientific Method, The, by H. E. Armstrong (21)

GENERAL

Age of Machinery, by A. R. Horne (6)
Age of Power, by J. Riley (30)
And Now All This, by W. C. Sellar & R. J. Yeatman (22)
Archimedes, by J. Heath (28)

Book of Electrical Wonders, by E. Hawks (17)
Boy Electrician, by A. P. Morgan & J. W. Sims (17)

Chats on Science, by E. E. Slosson (1)
Cinema in the School, The, by W. H. George (26)
Class-room Science—(Pupils' Book) Vols. I, II, III IV, by W. B. Little (24)
Coal and What We Get from It, by R. Meldola (28)
Common Science, by C. W. Washbourne (3)
Conquests of Engineering, by C. Hall (6)

Discovery of Circulation of Blood, by C. Singer (3)
Discovery, The Spirit and Service of Science, by R. A. Gregory (21)

Electrical Amusements and Experiments, by C. R. Gibson (29)
Electricity, by W. F. F. Shearcroft (17)
Elements of General Science, by O. W. Caldwell & W. L. Eikenberry (15)
Elementary General Science, by A. T. Simmons & L. M. Jones (21)
Elementary General Science, by T. A. Rama Iyer, V. Srinivasan and S. Swaminathan (25)
Every Boy's Book of Hobbies, by C. H. Bullivant (24)
Every Girl's Book of Hobbies, by E. M. De Foubert (19)
Everyday Science, by L. M. Parsons (21)
Everyday Science Topics, Books I, II and III, by T. A. Tweedle (17)

Fairy Land of Science, by A. B. Buckley (21)
First Book of General Science, by A. T. Simmons & A. T. V. Gale (21)
First Book of Rural Science, A, by J. J. Green (21)
Fun with Mechanics, by H. McKay (21)
Fundamentals of Radio, by Henry L. Williams (24a)

Gardening for Schools, by W. B. Little (26)
General Science, by L. Elhuff (18)
General Science, by G. Thompson & G. H. Leslie (9)

General Science, Parts I and II, by S. Whitehouse and A. W. Pritchard (25)
General Elementary Science, by W. Willings (6)
Gramophone in Education, The, by W. Johnson (26)
Great Inventions and How they were Invented, by C. R. Gibson (29)
Great Scientists, Living Biographies of, by Henry Thomas and Dana Lee Thomas (7a)
Guide to Electricity for Home and School, by C. F. Smith (25)

Heroes of the Scientific World, by C. R. Gibson (29)
Home Preservation of Fruit and Vegetables, by M. J. M. Watson (25)
Housecraft Science, by E. D. Griffiths (22)
How Aeroplanes Fly, by W. O. Manning (25)
How It is Made, by A. Williams (24)
How It Works, by A. Williams (24)
How Man Conquered Nature, by M. J. Reynolds (21)
How Things Behave, by J. W. N. Sullivan (5)

Introduction to General Science, by W. R. Fielding (17)
Introduction to General Science, Parts I and II, by W. L. Whiteley and A. S. Rowlatt (33)
Introduction to Physical Science, by I. B. Hart (25)
Introductory Textbook of Science, by E. J. Holmyard (21)

Lime and Cement, by W. J. Claxton (6)

Makers of Science, by I. B. Hart (25)
Makers of Science, by E. J. Holmyard (21)
Makers of Science Series—Electricity and Magnetism, by D. M. Turner (25)
Marvels of Mechanical Invention, by T. W. Corbin (29)
Marvels of the Railways, by A. Williams (29)
Marvels of Ships, by E. K. Chatterton (19)
Mastery of Air, by A. T. McDougall (26)
Mastery of Earth, by A. T. McDougall (26)
Mastery of Fire, by A. T. McDougall (26)
Mastery of Water, by A. T. McDougall (26)

Nature's Giant Forces, by A. T. McDougall (26)
Nature's Mystic Movements, by A. T. McDougall (26)
Nature's Wondrous Laws, by A. T. McDougall (26)

Outlines of Science, Vols. I & II, by J. A. Thomson (35)

Photography of Today, by H. C. Jones (29)
Power, by Martin Ruhemann (30a)

Rambles in Science Series—(a) *Wireless*, (b) *How Photography Came About*, (c) *Electricity as a Messenger*, (d) *The Mysterious Ocean of*

Ether, (e) *Telephones and Gramophones*, (f) *How We Harness Electricity*, by C. R. Gibson (6)
Readable Relativity, by C. V. Durell (3)
Romance of Modern Astronomy, by H. McPherson (29)
Romance of Modern Engineering, by A Williams (29)
Romance of Modern Invention, by A. Williams (29)
Romance of Modern Manufacture, by C. R. Gibson (29)
Romance of Modern Railways, by T. W. Corbin (29)
Rubber and its many uses, by H. McKay (25)

Science and Health, by W. B. Little (26)
Science and the Living Things, by W. B. Little (26)
Science and the Weather, by W. B. Little (26)
Science at Your Service, by Julian S. Huxley (1)
Science for All, by C. S. Sherrington (3)
Science from an Easy Chair, by Sir E. R. Lankester (22)
Science in Education, by W. B. Little (26)
Science in the City, by W. B. Little (26)
Science in the Country, by W. B. Little (26)
Science in the Home, by W. B. Little (26)
Science in Industry, by A. M. Low (25)
Science of Common Life, by A. T. Simmons (21)
Science of Everyday Life, by E. F. V. Buskirk and E. L. Smith (11)
Science lifts the Veil, by Sir William Bragg (20)
Scientific Amusements, by 'Tom Tit' (24)
Scientific Inventions, by T. W. Corbin (29)
Short Stories in Science, by J. G. Crowther (27)
So This is Science!, by H. F. Ellis (22)
Stars and their Mysteries, by C. R. Gibson (29)
Stories of Great Craftsmen, by S. H. Glenister (17)
Stories of Scientific Discoveries, by D. B. Hammond (8)
Story of a Coal Mine, by T. W. Berry (26)
Story of William Caxton, by S. Cunnington (17)

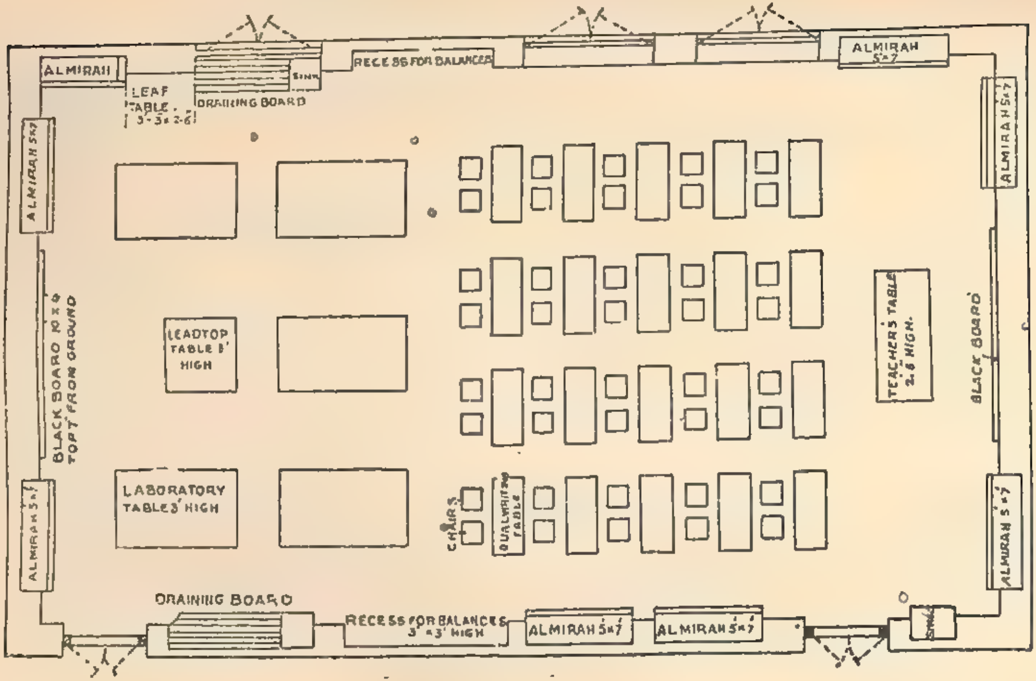
Telephones and Gramophones, by C. R. Gibson (6)
Things to Make, by A. Williams (24)
Things Worth Making, by A. Williams (24)
Thinking It Out, by A. Williams (24)
Toys and Inventions, by H. McKay (25)
Triumph of Man, by A. T. McDougall (26)

Victories of the Engineer, by A. Williams (24)

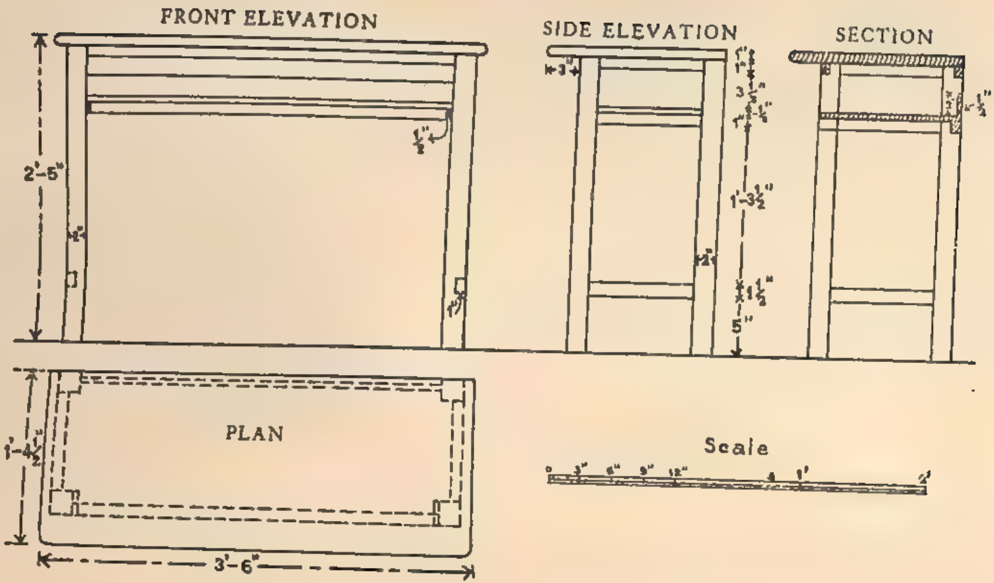
Wireless, by C. R. Gibson (6)
Wonders of the Universe, by H. E. Taylor (26)
Wonders of Transport, by C. Hall (6)

I. LABORATORY PLAN

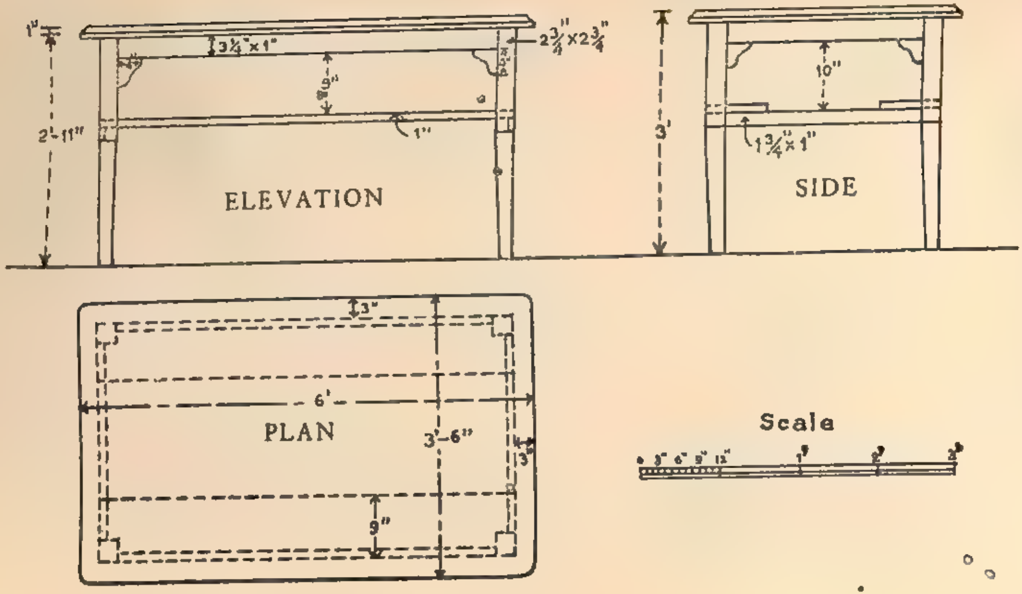
40 Students for demonstration, 20 for practical work



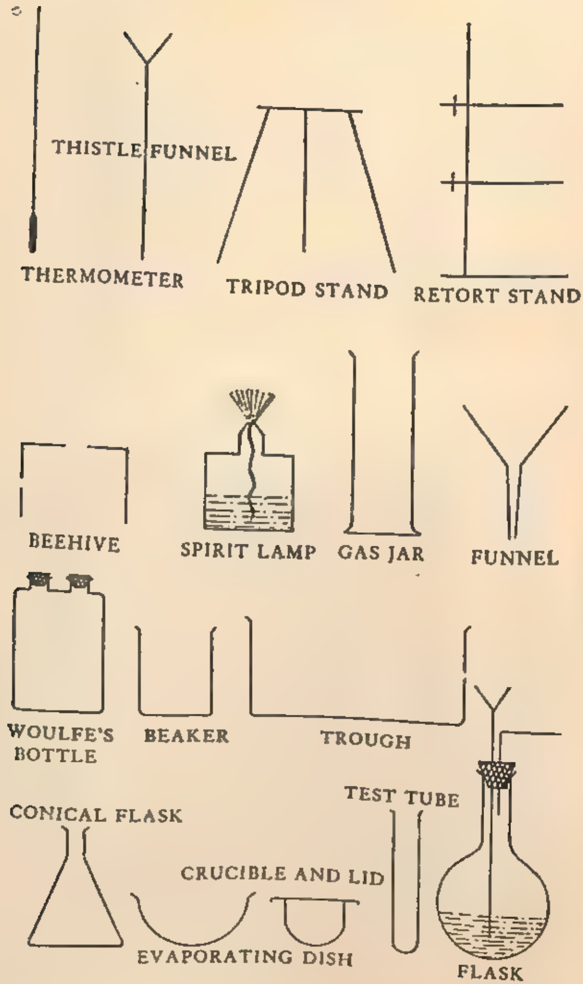
II. DUAL TABLE



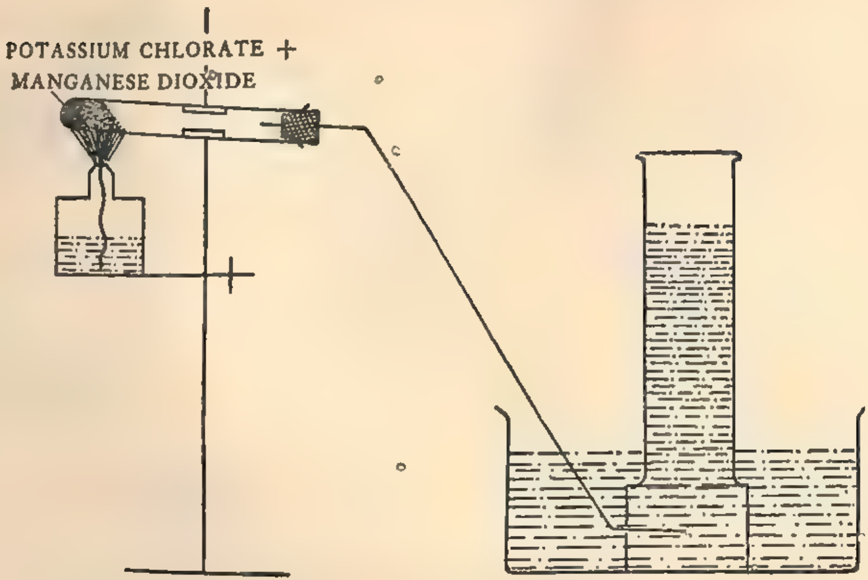
III. LABORATORY TABLE



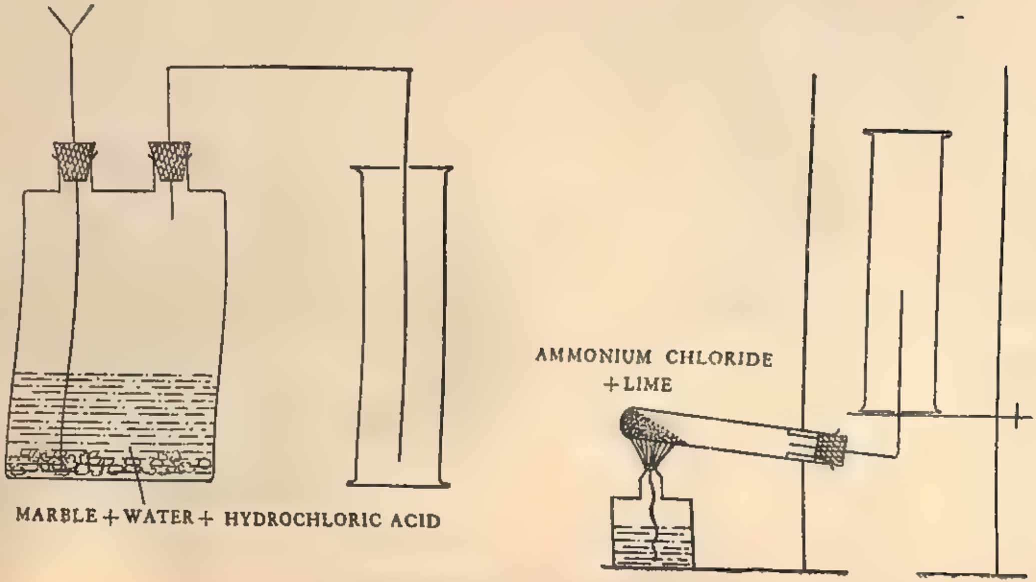
IV. COMMON ARTICLES USED IN PRACTICAL WORK



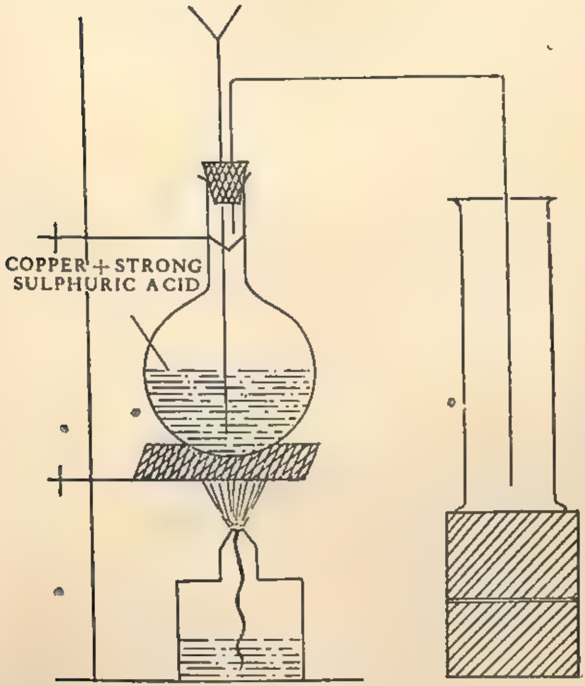
V. PREPARATION OF OXYGEN



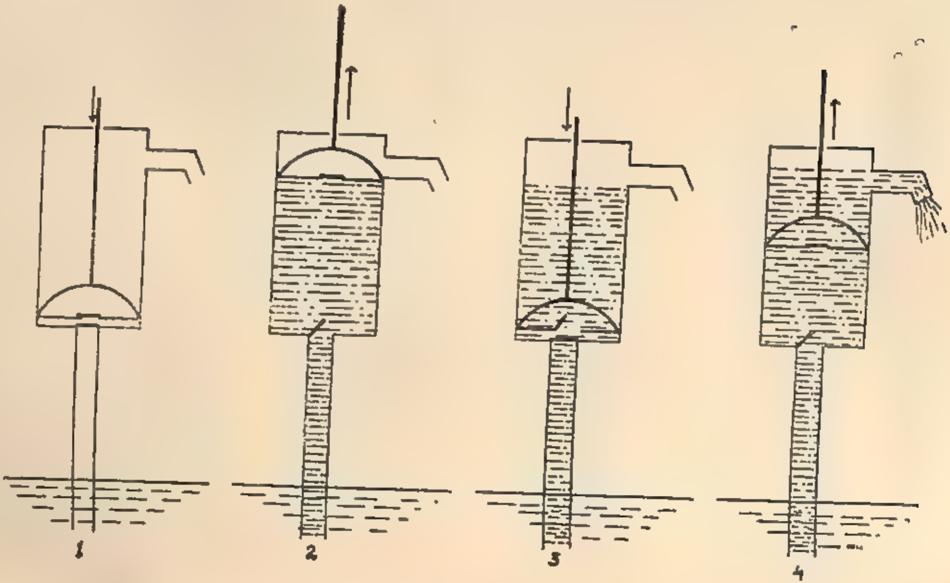
VI. PREPARATION OF CARBON DIOXIDE (left) & AMMONIA



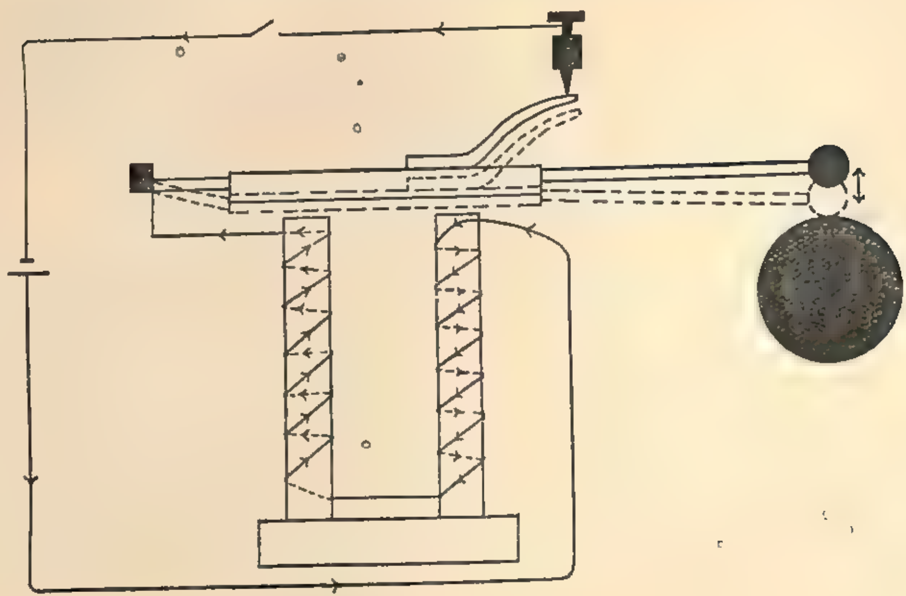
VII. PREPARATION OF SULPHUR DIOXIDE



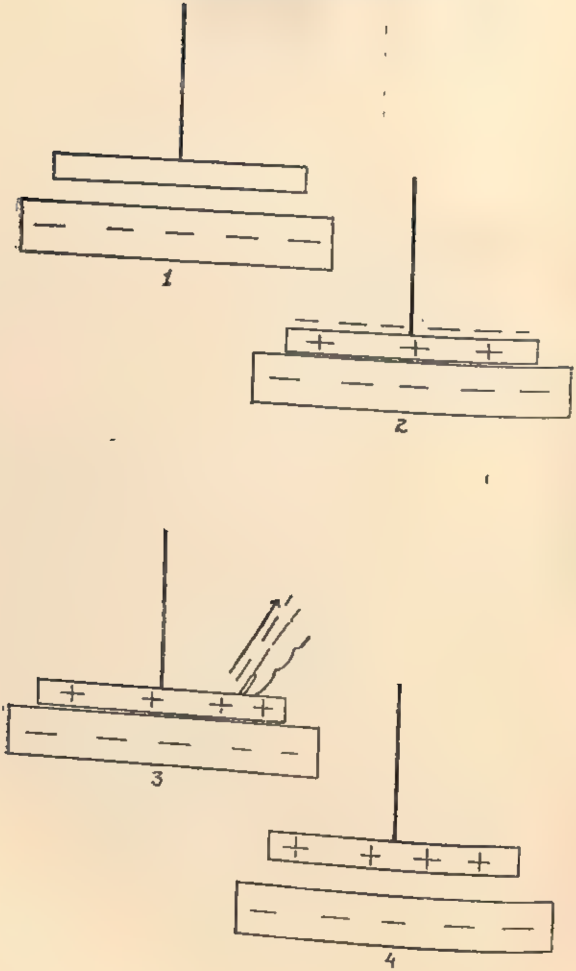
VIII. WORKING OF A WATER PUMP



IX. WORKING OF AN ELECTRIC BELL



X. WORKING OF AN ELECTROPHORUS



XI. SPECIMEN OF PERMANENT STOCK REGISTER

Permanent Stock Register										
Serial Number	Description of Stores	Number or quantity in hand on 1st April 196...	196...				196...		(Repeat last seven columns as desired for required number of years)	Remarks
			No. and date of order	Cost		Received	Struck off	In hand on...		
				Rs.	np.					

XII. SPECIMEN OF CONSUMABLE STOCK REGISTER

Consumable Stock Register						
Name of Article						
Date	Receipts		Expenditure		Balance in hand	Remarks
	Whence received	Amount received	How expended	Amount expended		

XIII. SPECIMEN OF PROGRESS CHART

PROGRESS CHART

__________School   __________   __________Term

__________Section   __________ 196   to__________196

No.	Name of Student	TERM EXAM. RESULTS			ASSIGNMENTS							No.
		I	II	III	1	2	3	....up to......	28	29	30	
1												1
2												2
3												3
up to												up to
48												48
49												49
50												50

XIV. SPECIMEN OF SCHOLAR'S CONTRACT CARD

SCHOLAR'S CONTRACT CARD

____

__________ School, __________

No. of periods in term ________

I solemnly promise that I will finish assignments Nos. __________

during this term (from ______ to ______)

Dated __________ 196 . Signature __________

Working Day	No. of Assign-ment	Teach-er's Initials	Working Day	No. of Assign-ment	Teach-er's Initials	Working Day	No. of Assign-ment	Teach-er's Initials
ADJUSTMENT WORK								

Contract completed __________ *Science Master*

Teacher's Report:—
English:
Spelling:
Writing:
Neatness:
Diagrams:
Accuracy:
General Remarks:

Date ________ __________ Science Master

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